HNOLOGY DEPARTMENT

December 1947

TECHNOLOGY REVIEW

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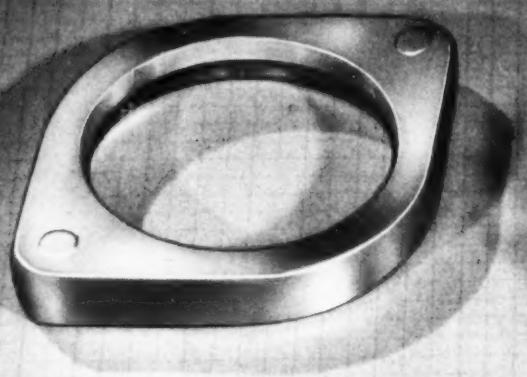
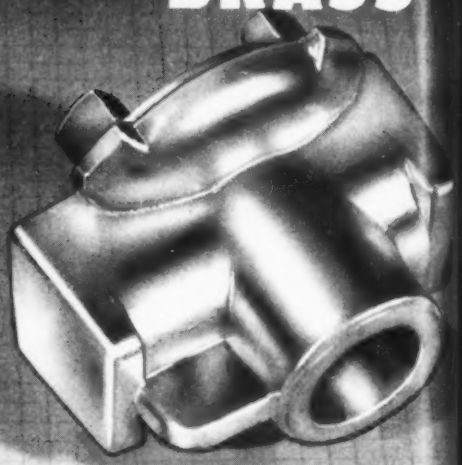
DETROIT

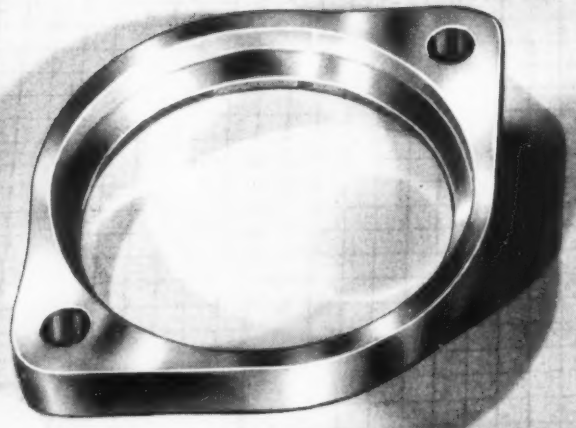
ALUMINUM

BRASS

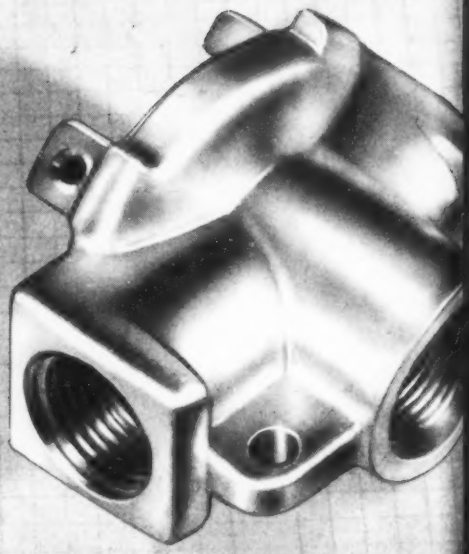


SMOOTH FORGED





MACHINED



THE HARVEY

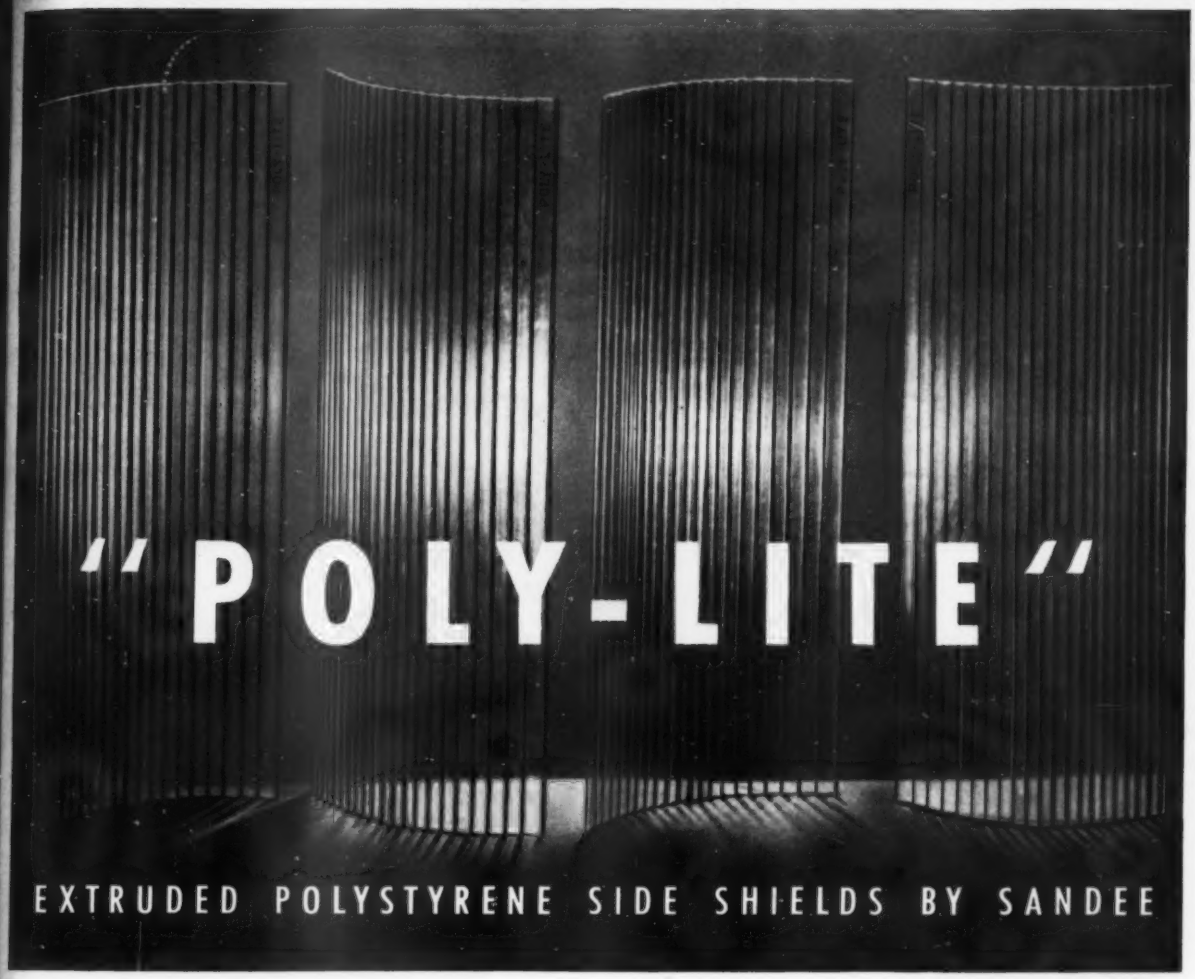
METAL CORPORATION

HAROLD B. HARVEY '05 • *Engineers & Manufacturers* • SHERRY O'BRIEN '17

74th STREET and ASHLAND AVENUE • CHICAGO 36, ILLINOIS

FORGINGS IN ALUMINUM • BRASS • BRONZE • COPPER • MAGNESIUM • MONEL • ALLOY

MACHINING FACILITIES



PLASTICS have long been recognized as a potential factor in reaching the ultimate in fluorescent lighting. Early trials failed however, because of either unsuitable materials, methods of fabrication, or both.

During the past three years Sandee has developed Polystyrene extrusions to a high degree of efficiency. Today, under the trade name "POLY-LITE" Sandee is manufacturing extruded Polystyrene Side Shields in ever increasing sizes and complicity of shapes. We are constantly adding more and more to the aesthetic and functional qualities of efficient modern fluorescent lighting.

The superior characteristics of Polystyrene in combination with Sandee extrusion technology is unsurpassed in guaranteeing the maximum in modern lighting efficiency! This combination is available to you on request in developing your individualized fixtures.

"POLY-LITE" IS A GUARANTEE OF QUALITY

SALES REPRESENTATIVES IN 19 PRINCIPAL CITIES

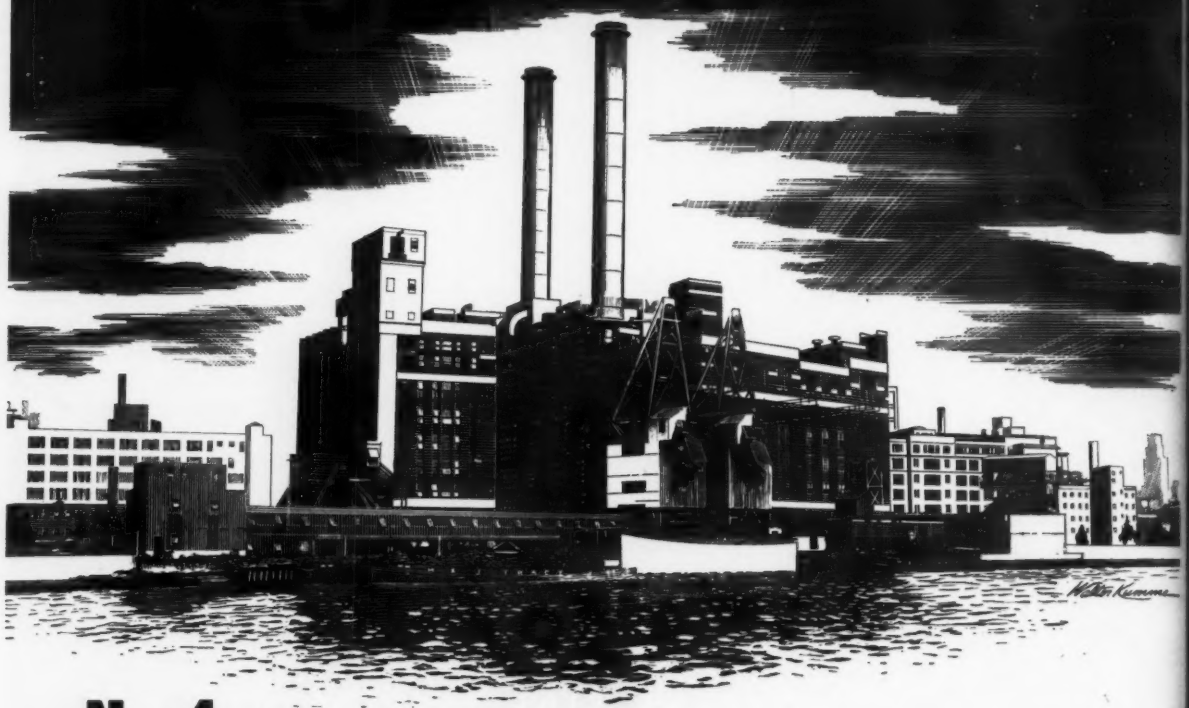
Sandee Manufacturing Company

5050 FOSTER AVENUE • CHICAGO 30, ILLINOIS

EXTRUDED PLASTICS AND SPECIAL TOOLS

THE TECHNOLOGY REVIEW, December, 1947. Newsstand Edition. Vol. L, No. 2. Published monthly from November to July inclusive at 10 Ferry Street, Concord, N. H. Publication date: twenty-seventh of the month preceding date of issue. Annual subscription $3.50; Canadian and Foreign subscription $4.00. Entered as second-class matter at the Post Office at Concord, N. H., under the Act of March 3, 1879.

History-making power stations



No. 4 – *East River Station* — CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

On November 23, 1926, Queen Marie of Rumania officially opened an electric generating station that made power history from its outset.

East River Station, located at the foot of 14th Street on the East River, was planned in 1924 to assume the rapid load growth of lower Manhattan. It was one of the early users of the completely water-cooled furnace and the first station in the Metropolitan area to use pulverized coal. Its six original boilers, each having a capacity of a quarter of a million pounds of steam per hour, were among the largest in the world.

Hardly had East River begun operation when the need for further expansion became evident. Accordingly plans were made for the addition of three more boilers to be ready for service in 1929. They were the first boilers in the world to generate a million pounds of steam per hour. In fact one unit has been operated at a rate of 1,270,000 pounds of steam per hour — still the highest rate on record. Some idea of the size of such a boiler may be had from the fact that a luncheon for 90 people was held in the furnace of one unit in celebration of its completion.

After eighteen years of service these boilers are still among the most efficient in the country and are also notable for their ability to burn any grade of bituminous coal available. The pulverized fuel equipment, water-cooled furnaces and air pre-heaters of the original installation and the three million-pound units, installed in 1929, are C-E design and manufacture throughout.

The long identification of Combustion Engineering equipment with history-making advances in steam generation at East River and other notable power stations is another reason for coming to C-E for your next boiler unit, whether your steam requirements be large or small.

These three factors are the unwritten plus-values in every C-E contract —

Knowledge — *to solve today's, and tomorrow's, steam generating problems.*

Experience — *to interpret, from a world-wide background in every important industry, the specific needs of each installation.*

Facilities —*to manufacture complete steam generating units for every capacity from 1000 pounds of steam per hour up to the largest.* B-147

COMBUSTION ENGINEERING

200 MADISON AVENUE • NEW YORK 16, N. Y.

Abrasive Products

Grinding wheels of ALUNDUM*, CRYSTOLON* and diamond abrasives; discs and segments; bricks, sticks and hones; mounted points; abrasives for polishing, lapping, tumbling and pressure blasting; pulpstones.

Grinding and Lapping Machines

A varied line of machines for production-precision grinding and lapping and for the tool room — including special machines for crankshafts, camshafts, rolls and car wheels.

Refractories

High temperature refractories — grain, cement, bricks, plates, tile, tubes — for metal melting, heat treating and enameling; for ceramic kilns; for boiler furnaces and gas generators; for chemical processes; refractory laboratory ware; catalyst carriers; porous plates and tubes.

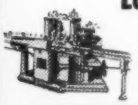
Norbide*

Trade-mark for Norton Boron Carbide — the hardest material made by man. Available as an abrasive for grinding and lapping; in molded products for extreme resistance to wear — especially effective for precision gage anvils and contact points; and for metallurgical use.

Norton Floors

ALUNDUM* Floor and Stair Tile, ALUNDUM* Ceramic Mosaic Tile and ALUNDUM* Aggregates to provide permanently non-slip (wet or dry) and extremely wear-resisting floor and stair surfaces.

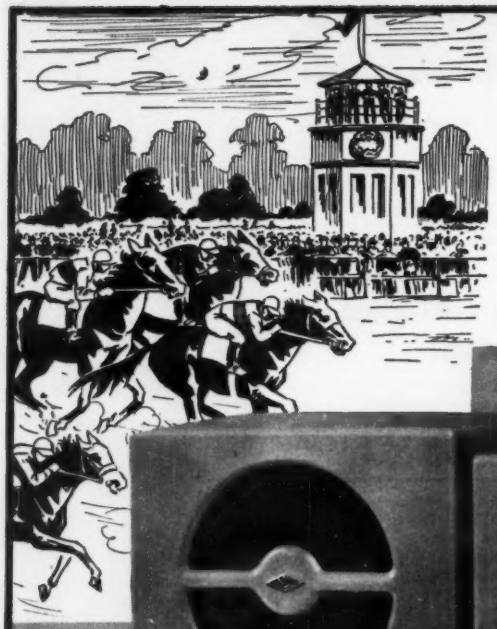
Labeling Machines



Single and duplex automatic labeling machines for applying labels and foil to beverage bottles and food, cosmetic and drug containers.

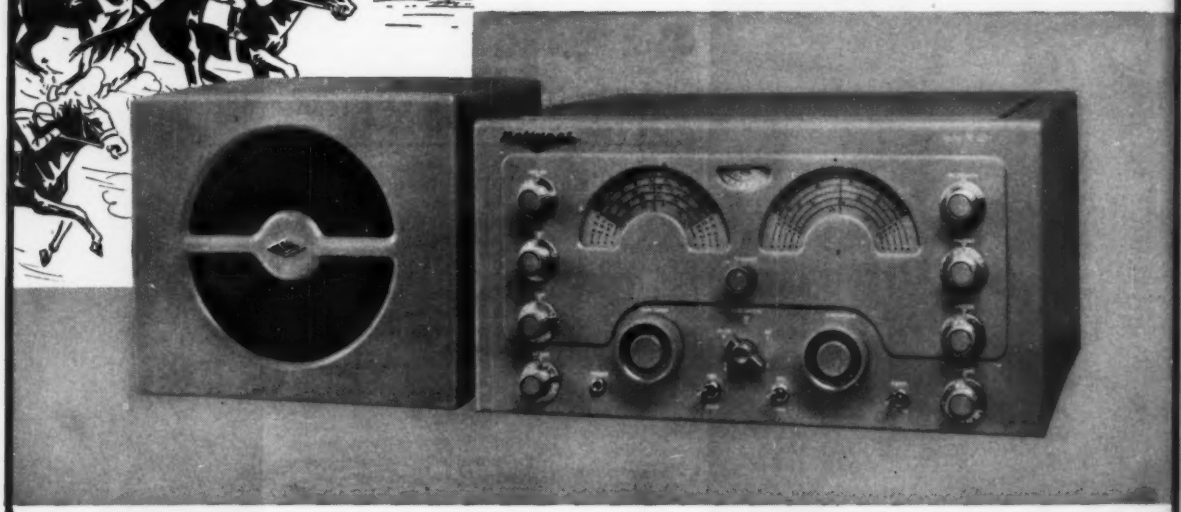
Oilstones and Coated Abrasives

Sharpening stones and abrasive papers and cloth for every use of industry and the home craftsman. Products of the Norton Behr-Manning Division, Troy, New York.



ANOTHER NATIONAL *FIRST*

THE NC-183



National NC EST. 1914

FEATURES:

- Frequency coverage from 0.54 to 31 Mc Plus 6 meter band. Band-switching on all frequencies.
- Adjustable sensitivity control for S-meter operation on either c.w. or phone.
- Automatic adjustable threshold double-diode noise limiter.
- 115 volts 50/60 cycle AC operation. Easily adapted to 230 volts.
- Amateur Net (Complete with 10" speaker).....$269.00

For the first time, a ham receiver incorporating *all* the latest innovations demanded by amateurs is now available at a reasonable price.

The NC-183, latest in National's great new line of communications receivers, is a band-switching set covering frequencies from 0.54 to 31 MC plus the 6 meter band. Two r.f. amplifier stages provide remarkable image rejection and the latest crystal filter aids in maintaining the highest degree of selectivity.

In addition, a stabilized voltage regulated circuit makes the NC-183 a truly top-flight performer on the highest frequencies. A push-pull audio output stage with separate 10" speaker affords excellent fidelity of output.

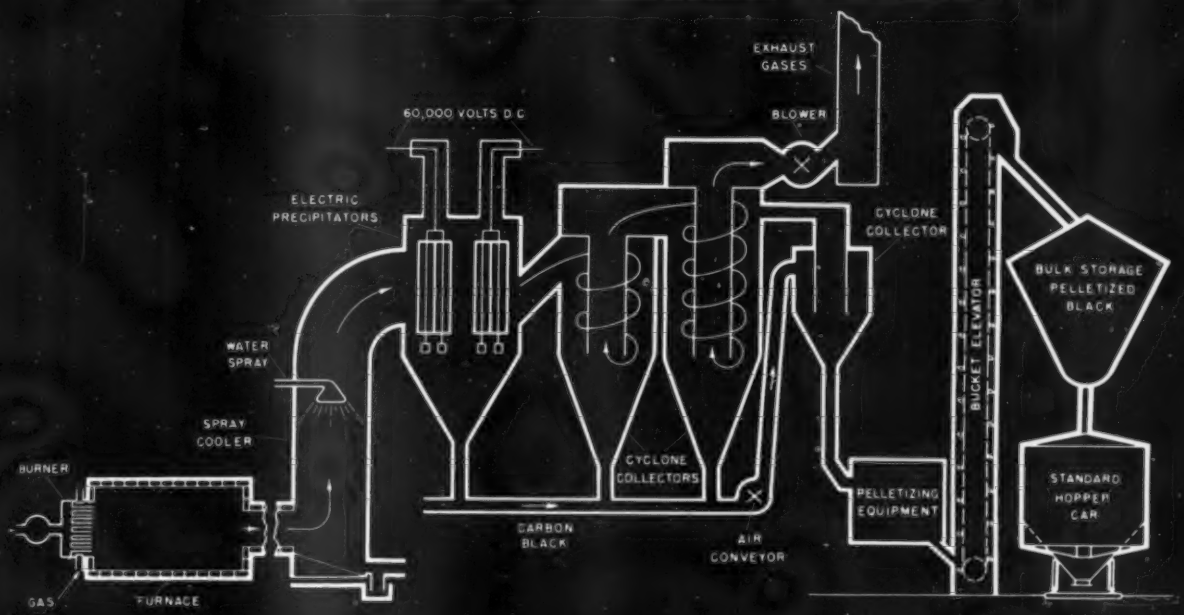
These, plus many other features, combine to make the NC-183 a really "hot" receiver. It will certainly become a strong favorite with those stations that specialize in digging DX out of the background.

See and hear the NC-183 at your nearest National distributor this week.

National Company, Inc.
Dept. No. 18
Malden, Mass.

MAKERS OF LIFETIME RADIO EQUIPMENT

CABOT CARBON BLACK



FURNACE PROCESS

A world of technical know-how goes into the manufacture, shipment and delivery of every pound of Cabot furnace-type carbon black. From the first stage of manufacture to delivery in CABX cars, which were designed by Cabot engineers and built to their specifications, every pound of Cabot furnace-type black is under precise control, every hour of every day, every step of the way.

A new technical bulletin on bulk handling of furnace type black in manufacturers' plants is available.

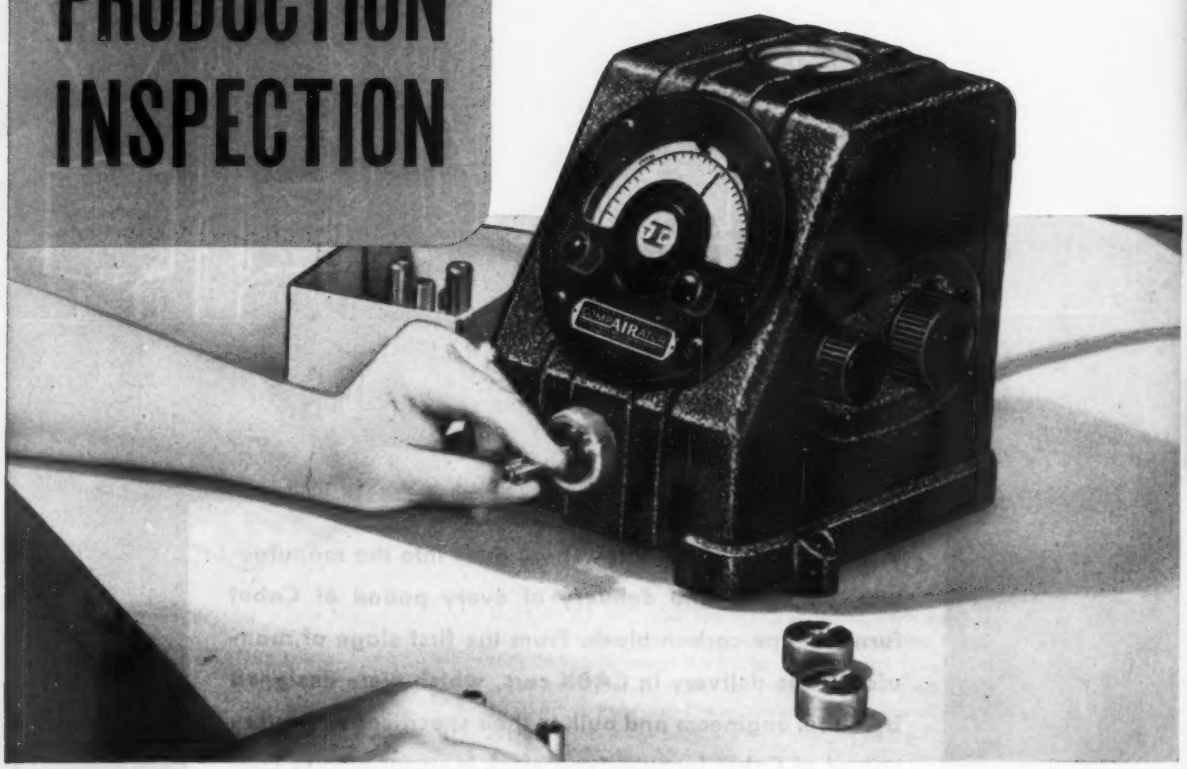
CABOT

GODFREY L. CABOT, INC.

77 Franklin Street, Boston 10, Mass.

Speed up and Save on PRODUCTION INSPECTION

...with the New TAFT-PEIRCE COMPAIRATOR AIR GAGE



Complete and self-contained to include regulator and filter, this modern air gage is 7" wide, 8½" deep, 8" high and weighs only 12 pounds.

All the operator has to do is to attach the hose to the air line. He needs no special skill to operate the gage, *which measures without mechanical contact.* He easily can check all variations such as taper, out-of-roundness, bell-mouth, and barrel-shaped conditions.

The T-P CompAIRator combines high sensitivity with easy readability. The dial indicator provides accurate readings, *free from pointer-flutter.*

Take the "air-way" to faster and more economical inspection at the machine, at the bench, or in the inspection room. Write for illustrated bulletin on the new CompAIRator to The Taft-Peirce Manufacturing Co., Woonsocket, Rhode Island.

T-P *means* TOP PRECISION

Use TAFT-PEIRCE Gages for Every Gaging Need...

MAGELLAN MIGHT HAVE MADE IT

IN 1519, Ferdinand Magellan set sail in five antiquated vessels in an attempt to circle the globe. He died before the voyage was completed although one of the ships did win through after three years of hardship. With power, even in its most elementary form, Magellan might have lived to see the success of his great adventure.

It was nearly three centuries until the successful voyage of "Fulton's Folly" proved that power at sea was practical. Since then, it has made giant strides of progress and in a short half century, Diesel engines have found an ever-growing usefulness.

Today, internal-combustion engines of all kinds are serving the world in its struggle for reconstruction.

AMERICAN BOSCH CORPORATION SPRINGFIELD 7, MASS.

SERVING POWER

American Bosch serves the internal-combustion-engine industry in three vital ways:

ENGINEERING. 1,200,000 *man-hours* of it have been poured into Diesel fuel injection alone—other millions into ignition.

PRODUCTION. *Premium performance* has been a consistent goal in the production of hundreds of thousands of Diesel injection systems and millions of electrical units.

MAINTENANCE. *The world over,* American Bosch authorized service stations keep the equipment operating efficiently.

AMERICAN BOSCH

PARTNERS IN THE PROGRESS OF POWER

DIESEL FUEL INJECTION • AUTOMOTIVE AND AVIATION ELECTRICAL PRODUCTS

FREE AS A BIRD!
with this more convenient
OIL DELIVERY!
FUEL OIL
Oil heat is modern heat. And when you specify oil heat in your home, specify VENTALARM,* too . . the audible fuel oil tank fill signal that makes fuel oil delivery completely automatic.
Installed on your fuel tank, the VENTALARM fill signal emits a whistling sound clearly audible through the vent pipe out-of-doors. Whistle stops when the tank is properly filled . . no guess work, no spillage, no waste, no delay!
With VENTALARM the driver never enters the home . . you needn't even be at home . . for oil delivery. VENTALARM is now installed by more than 3500 oil burner and fuel oil dealers. Ask for it!
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Cambridge, Mass.
CANADIAN LICENSEE
EMPIRE BRASS CO., LTD., LONDON, ONTARIO
Write today for colorful, free VENTALARM booklet.
Increase THE COMFORT AND PROTECTION OF YOUR HOME

VENTALARM

T. M. Reg. U. S. Pat. Off.

WHISTLING FILL SIGNAL

is also standard equipment on fifteen makes of automotive vehicles.

VENTALARM
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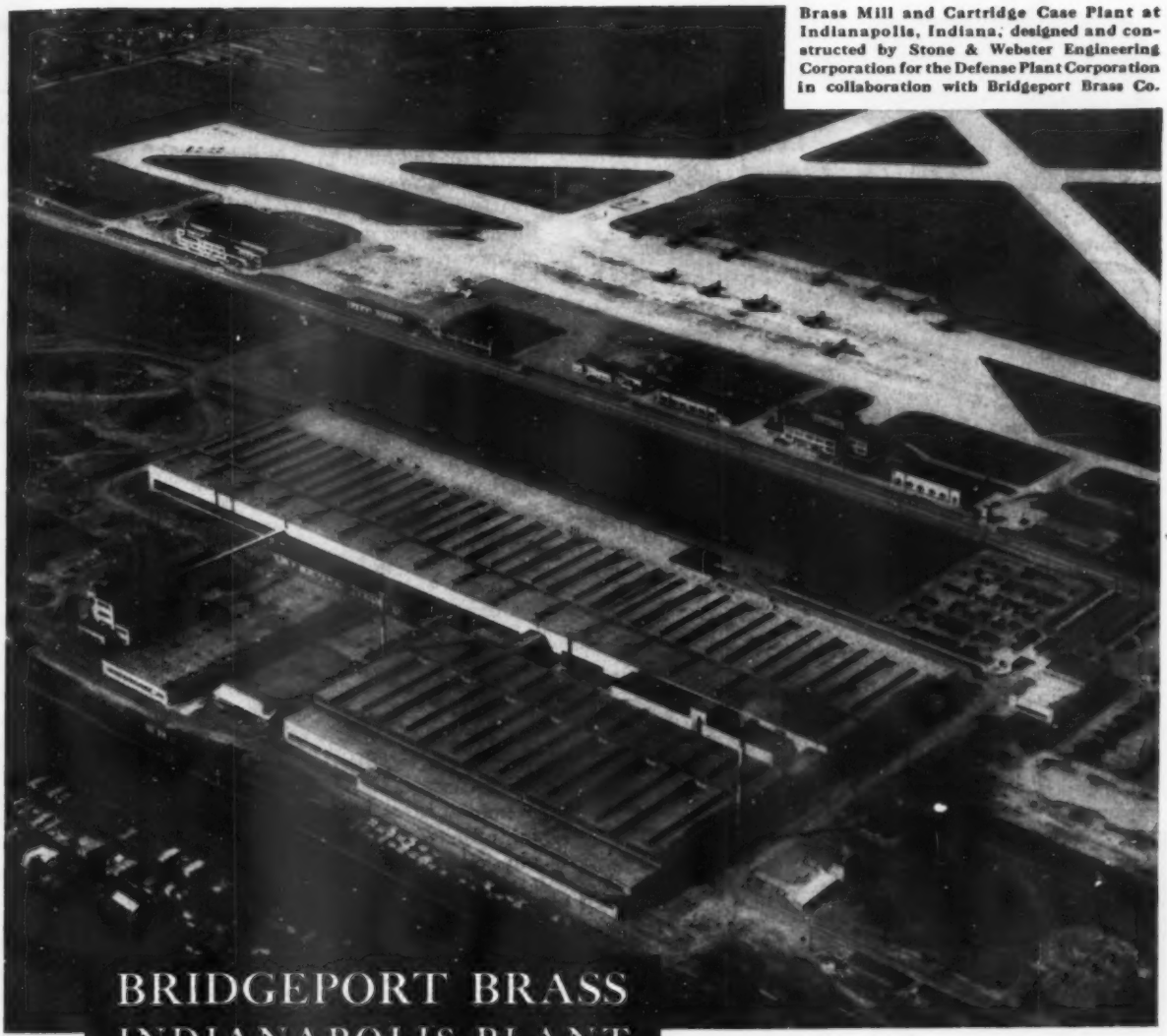
88 First Street • Cambridge 41, Mass.



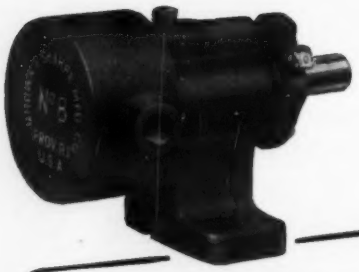
Brass Mill and Cartridge Case Plant at Indianapolis, Indiana, designed and constructed by Stone & Webster Engineering Corporation for the Defense Plant Corporation in collaboration with Bridgeport Brass Co.

IN designing and constructing the Brass Mill and Cartridge Case Plant at Indianapolis, Stone & Webster Engineering Corporation collaborated with Bridgeport Brass Company engineers . . . Provision had to be made for the immediate and variable needs of wartime production . . . During the war it proved to be one of the lowest cost producers of cartridge brass in the country.

Today this efficient plant is again in operation as Bridgeport's mid-western brass mill. The shifting demands of peacetime production were met with a minimum of changes. It stands as an example of sound engineering . . . planned for future needs.

STONE & WEBSTER ENGINEERING CORPORATION

A SUBSIDIARY OF STONE & WEBSTER INC.



No. 8 Vane Pump operates in either direction

... For circulating oil to cutting tools of light metal working machines or for lubricating mechanical units.

Two vanes, rotating in an eccentric ring, alternately produce suction and compression. This gives a constant flow in one direction whichever way driving shaft is rotating. Either side of pump can be used for suction by making a simple adjustment. For construction details and installation dimensions, write Brown & Sharpe Mfg. Co., Providence 1, Rhode Island.

GEARED • VANE • CENTRIFUGAL • MOTOR DRIVEN B&S

BROWN & SHARPE PUMPS

HEVI DUTY

Hevi Duty Electric Co.

Surges Transformers

With the acquisition of the Surges Electric Company of Milwaukee, Hevi Duty can now offer quality dry type air cooled transformers with or without tap changing switches as well as special transformers for special requirements. An accelerated program of modernization will present opportunities for increased production and good delivery schedules.

Write for Bulletin S-4611

HAROLD E. KOCH '22, *President*

ELTON E. STAPLES '26, *District Manager, Cleveland*

HEVI DUTY ELECTRIC COMPANY

HEAT TREATING FURNACES HEVI DUTY ELECTRIC EXCLUSIVELY

MILWAUKEE 1, WISCONSIN

THE TABULAR VIEW

Concerted Attack.—Science cannot yet promise a cure for cancer. Nevertheless, physicians and electrical engineers are, and for many years have been, making a concerted attack on this problem to supplement surgical treatment through the application of roentgen rays to the affected regions of the body. Promising as were some of the early researches in this field, it is now possible to record accelerated progress in the treatment of deep-seated malignancies as a result of physical and clinical research conducted during the last decade. Multimillion-volt generators for producing x-rays, combined with clinical techniques for effectively utilizing such radiation at the malignancy without harming adjacent tissues, have played a major role in recent studies, as JOHN G. TRUMP, '33, relates (page 91) in "Roentgen Rays against Cancer." Professor Trump received his bachelor's degree in electrical engineering from the Polytechnic Institute of Brooklyn in 1929, a master of arts degree from Columbia University two years later, and the doctorate of science from M.I.T. in 1933. He was a research associate at the Institute from 1933 to 1936 and since 1936 has been a member of the Faculty. Currently, he is associate professor of electrical engineering and chairman of the Faculty Club. Professor Trump's research at M.I.T. on supervoltage roentgen ray generators for the treatment of deep-seated malignancies has been carried on with the co-operation of physicians at the Massachusetts General Hospital, Harvard's Huntington Memorial Hospital, and the American Oncologic Hospital in Philadelphia in a program in which engineers and physicians alike are making a concerted and effective attack on cancer.

Tomorrow's Metals.—Those metals which are in greatest use today are not necessarily those which will be most diligently sought after by future generations. In fact, current indications are that, at the present rate of production and consumption, a number of metals essential to our present-day economy may well become exhausted in the lifetime of persons now living. Indeed, we are coming to recognize generally that our metals are by no means inexhaustible — a statement which is also true of other natural resources. How long, then, may we draw upon our mineral resources at our present rate of use? What metals does the United States consume in greater quantities than it produces? How can this country best husband and use supplies of metals for which it is not self-sufficient? In "How Long Will Our Metals Last?" CARLE R. HAYWARD, '04, Emeritus Professor of Process Metallurgy, skillfully sets forth (page 96) authoritative views on this timely topic. A program of conservation which Professor Hayward proposes is one the adoption of which would benefit all nations. A recognized authority on process metallurgy, Professor Hayward has written extensively in his field, and has dealt especially with copper, lead, and zinc — all metals for which this country's demand may soon seriously outstrip its domestic supply. A native of Yankton, S. D., Professor Hayward became an instructor in science at the Bellows Free Academy in Fairfax, Vt., following his graduation from M.I.T. in 1904. In 1906 he joined the Institute's

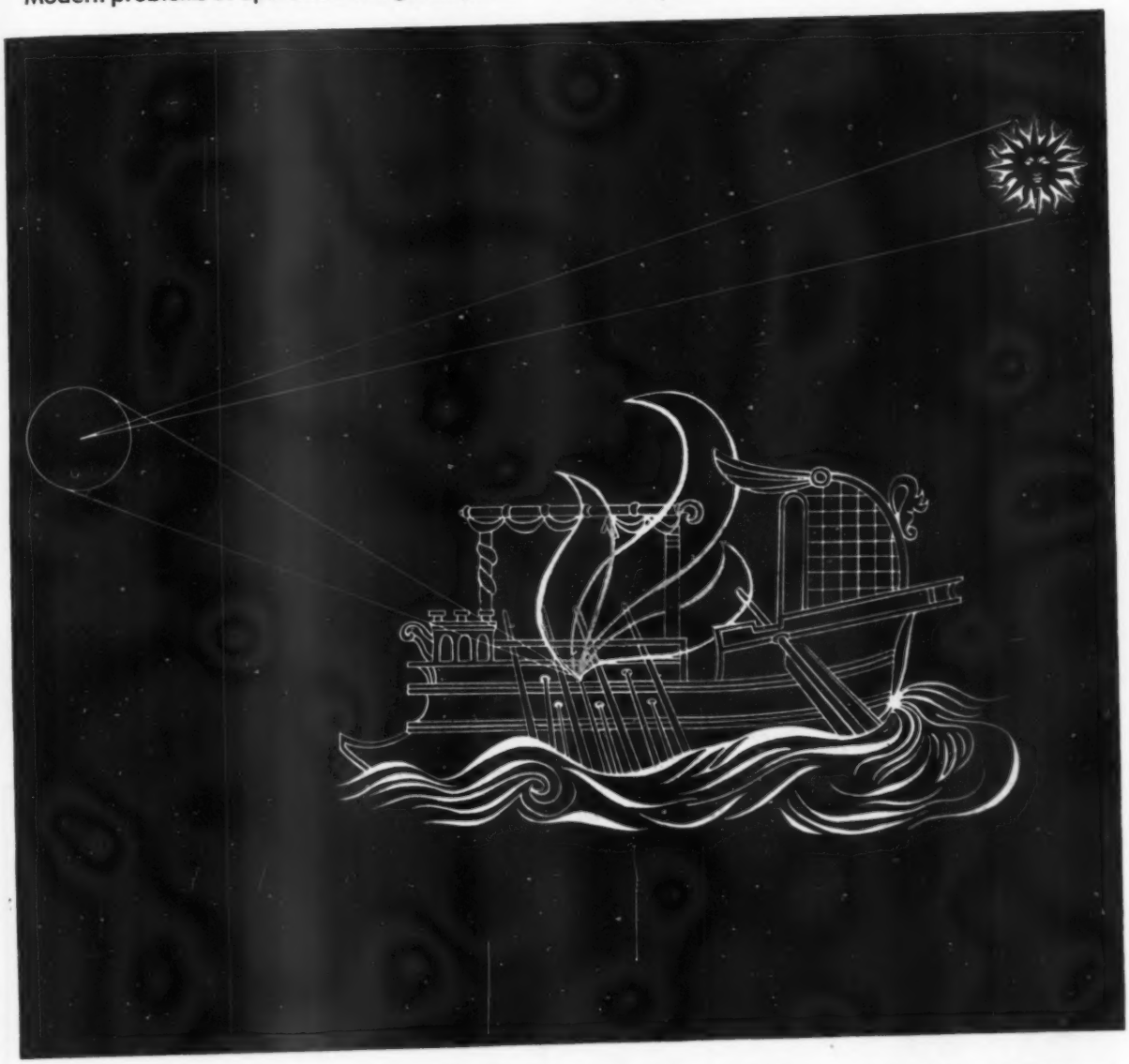
(*Concluded on page 84*)

IT ISN'T DONE WITH MIRRORS—TODAY

When the Roman fleet tried an amphibious operation at Syracuse, they ran into a problem of high temperature condition that completely nonplussed them. Archimedes, according to legend, burned them up by focusing the sun's rays on them with mirrors.

Modern problems of operation at high temperatures are solved quite simply by using molybdenum steels. Their creep strength and excellent properties at elevated temperatures assure good performance when the heat is on.

We will be glad to send detailed information concerning the types of molybdenum steel suitable for operation at elevated temperatures.



MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"
CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

Climax Molybdenum Company
500 Fifth Avenue • New York City

MOLY

TO GET THE MOST OUT OF HACKSAWS AND BAND SAWS

Starrett Hacksaw Booklet "L" describes the complete line of Starrett Hacksaw Blades for hand frame and hacksaw machine and Starrett Band Saws for cutting metal, wood and other materials. Starrett Cutting Chart instantly gives complete information for cutting any material by hacksaw or band saw. Write for copies.

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Let's Be Correct . . .

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Precision practices have been developed in every department at Diefendorf.

Gears for nearly all purposes—of all metals—and non-metallics as well. Custom made, exclusively, to your most precise specifications.

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DIEFENDORF GEAR CORPORATION

Syracuse 1, New York

DIEFENDORF GEARS

THE TABULAR VIEW

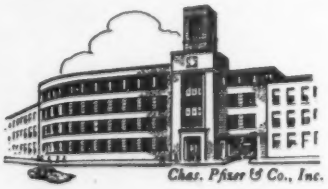
(*Concluded from page 82*)

instructing staff. He has long been sought as a consultant in his field and assisted in developing the present process for producing oxygen-free copper. He has also translated a number of books in the field of metallurgy.

Automatic Control. — When the Wright brothers first lifted their heavier-than-air machine at Kitty Hawk, N. C., airplane controls were few and simple, and what navigation was required could be carried out by direct observation. As the speed and complexity of aircraft increased throughout the years, the pilot was forced more and more to depend upon instruments to aid his flying. Now, with airplanes traveling at velocities near that of sound, it is becoming increasingly necessary to replace human control by automatic control of aircraft, as ROBERT C. SEAMANS, '42, relates (page 102). Not only does automatic control minimize fatigue of operating personnel in planes in which it is currently employed, it also increases the reliability of flying in all kinds of weather, and makes possible new uses for airplanes. Upon receiving his bachelor's degree from Harvard University in 1940, Mr. Seamans came to M.I.T. for graduate study in aeronautical engineering and received his master's degree in this field in 1942. He was appointed an instructor in 1941 and in 1945 was promoted to assistant professor of aeronautical engineering. In addition to his teaching, he is currently engaged in research on aircraft controls in the Instrumentation Laboratory directed by Professor Charles S. Draper, '26. His article "Automatic Control of Aircraft" is the result of recently conducted research in this laboratory.

Rogers Building. — Illustration on the Contents page shows the main entrance of the Rogers Building where photoelectric controls open the heavy doors to welcome students, Faculty, and guests. The photograph was made by an M.I.T. student, DANIEL S. MCDERMOTT, '50, whose work has also appeared in Boston newspapers.

Speed with Economy



The ability to build *quickly* and *well* is not acquired overnight . . . When you engage us, you have an organization that has been geared for fast, closely-coordinated service ever since its formation — 30 years ago.

W. J. BARNEY CORPORATION

101 PARK AVENUE, NEW YORK

INDUSTRIAL CONSTRUCTION

Alfred T. Glassett, '20, Vice President

"—mountains are leveled and oceans bounded by the slender force of human beings"—SAMUEL JOHNSON

Why communications get better all the time

YOUR VOICE girdles the globe in one-seventh of a second.

It travels at 186,000 miles per second—the speed of light—thanks to the telephone and radio. And by television, so do the pictures of any event as it occurs.

What has made this blinding speed possible? What has given us these "ringside seats" . . . to see, to hear, to share in the headline news of the day?

The answer: Greater knowledge of electronic waves and better materials to harness them. For example, the vacuum tube—heart of radio or television—depends upon the greatest possible absence of air or other gases—a high vacuum. Most of the air is pumped out before the tube is sealed. Then a tiny bit of barium, called a "*barium getter*" is flashed inside of it by electricity. This captures the remaining air and gives a nearly perfect vacuum.

Unending research and engineering have also provided finer plastics for insulation, purer graphite and carbon for electronic devices . . . and a host of other basic materials that help shave the speed of communications to the tiniest splinter of a second.

Producing these better materials and many others—for the use of science and industry and the benefit of mankind—is the work of the people of UNION CARBIDE.

FREE: *You are invited to send for the illustrated booklet, "Products and Processes," which describes the ways in which industry uses UCC's Alloys, Carbons, Chemicals, Gases and Plastics.*

UNION CARBIDE
AND CARBON CORPORATION

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KEMET GETTERS • NATIONAL CARBONS • EVEREADY FLASHLIGHTS AND BATTERIES • ACHESON ELECTRODES

Leading auto makers switch to new kind of tire

Call Super-Cushion by Goodyear greatest tire advance in 15 years

Bigger, softer tire runs on only 24 pounds of air; gives incredibly smoother ride, greater mileage and safety, better car handling

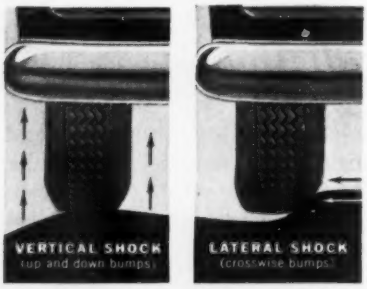
MANY LEADING auto makers are switching to a new *kind* of tire for their latest cars.

The automobile engineers who tested the new Super-Cushion by Goodyear said: "We want this tire for our new cars—*now!*" Here's *why* they didn't want to wait:

First tire to lick lateral shock

Till Goodyear produced the Super-Cushion, lateral (crosswise) shock was one of the few things yet to be licked in the modern motor car. Pillowy Super-Cushions soak up crosswise jolts.

This means not only a more luxurious ride—but less wear and tear on *every part of your car*. Result: *longer life for your car!*



• This shows the two kinds of road shock your car gets. The new Super-Cushion by Goodyear is the first tire to lick lateral shock.

• Leading car makers found Super-Cushions made an astonishing improvement in motor car operation. They said: "We want them for our new cars *now!*" In 1948 Super-Cushions will be standard equipment on many new cars.

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The new *Super-Cushion*

by GOODYEAR

VOL. 50 No. 2

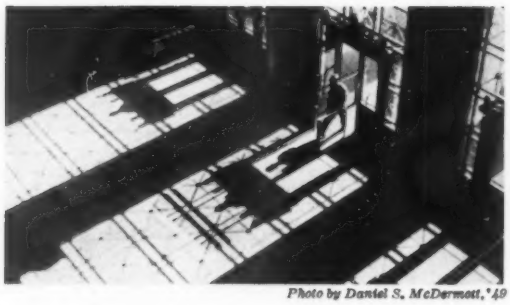

Photo by Daniel S. McDermott, '49

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Photo by Mayer from Black Star

Sundown on the Cuyahoga Valley steel industry

THE
TECHNOLOGY
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Vol. 50, No. 2 December, 1947

The Trend of Affairs

Cold — on Tap

THERMAL motion of the molecules masks the effects predicted by the laws of quantum mechanics. It is for this reason that temperatures near absolute zero are essential for much research directed toward a better understanding of the properties of matter. The true equilibrium state of many chemical reactions, for example, can be determined from thermodynamic constants which can be computed from measurements made at very low temperatures. But research at temperatures near absolute zero has been seriously hampered, heretofore, because scientists have been forced to devote a disproportionate amount of time and effort to the wholly subsidiary problem of first obtaining low temperatures. Now the commercial availability of a refrigerator par excellence, the helium cryostat, removes this obstacle as a deterrent to low-temperature research. With temperatures of within two or three degrees of absolute zero on tap research workers can go about their intended investigations, freed from the plague of operational details implied by the second law of thermodynamics.

Packaged cold may now be delivered from a helium liquefying refrigerator cabinet five feet high and occupying a floor space of six square feet, exclusive of a ten-horsepower compressor and low-pressure gas container. The complete unit weighs about 2,800 pounds, occupies less than 50 square feet of floor space, and starting from room temperature can reach a temperature of two degrees Kelvin in about two hours.

Inventor of the helium cryostat is Samuel C. Collins, Associate Professor of Mechanical Engineering at M.I.T., who assisted Dr. Howard O. McMahon, '41, and Allen Latham, Jr., '30, of Arthur D. Little, Inc. in the development of the commercial units. In a paper presented before the American Institute of Chemical Engineers in Detroit on November 11, Messrs. McMahon and Latham described the engineering details of the Collins helium cryostat, although a preview of this important development was recorded in the article "Progress in Low Temperature Refrigeration" by Dr. Collins in the January, 1947, issue of The Review.

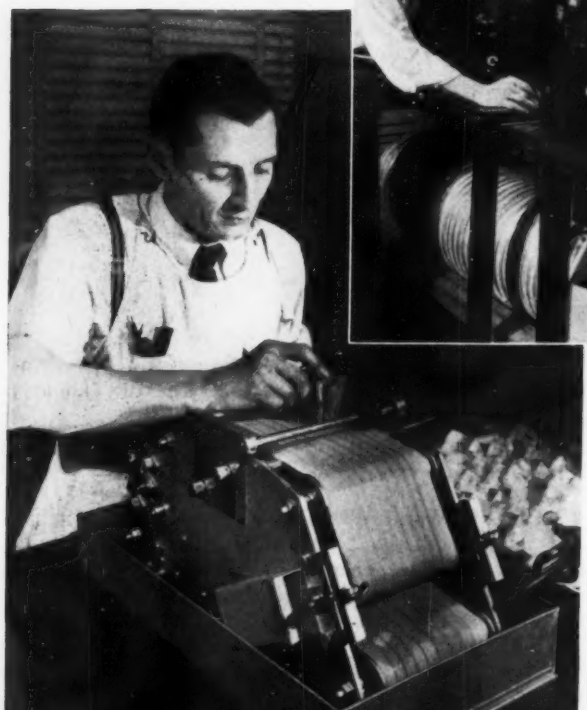
Cultured Crystals

DURING World War II the American and British navies sank about 1,000 enemy submarines. One of the most important weapons in this underwater warfare was sonar, the recently developed system for locating, tracking, and ranging underwater targets by sound waves. In most of these sonar gears the actual generating and detecting of the sound waves were done by a multiplicity of piezoelectric crystals which change their dimensions slightly when placed in an electric field, or conversely, which generate a tiny electric potential difference between opposite faces when the crystals are stressed mechanically. Quartz, Rochelle salt, and tourmaline are among the better known examples. Such crystals are fairly common household items, for many home phonographs have a small Rochelle salt crystal in their pickup arms. When vibrated by the needle as it follows the record groove, the crystal generates an electric voltage of corresponding wave form which eventually emerges from the loud-speaker as music. For some of the more exacting requirements of electronics, and particularly for establishing the carrier frequency at which radio transmitters generate their signals, quartz crystals are required in such quantities that during the war they were one of our high priority imports.

In a search for materials having more desirable performance characteristics than either quartz or Rochelle salt, the designers of one of our most widely used sonar gears picked crystals of ammonium dihydrogen phosphate (ADP for short) to serve as their transducers in converting the actuating electrical energy into the actual sound waves in the water. A companion type of synthetic crystal is potassium dihydrogen phosphate, or KDP. About 20,000,000 crystals of these types have been produced.

Under a rigid schedule of temperature control, large crystals of ethylenediamine tartrate are painstakingly grown at the Bell Telephone Laboratories before finding their ultimate use in communication equipment. At the right are shown a number of EDT crystals which have already grown to considerable size. Before the crystals are suitable for use, they must be cut to approximate size and then ground and polished to the desired dimensions, as shown below.

Photos by Nick Lazarnick



Since there is no natural source for either one of these crystals, they were grown synthetically in a manner that quickly took on the characteristics of a high production, highly mechanized industry. A substantial precedent exists, of course, in the well-established practices for growing Rochelle salt crystals from supersaturated water solutions.

A new competitor of quartz, recently announced by the Bell Telephone Laboratories, is ethylenediamine tartrate, or EDT, for which the principal peacetime use is in telephone equipment. Facilities for producing this type of crystal by the hundreds of thousands annually are now available. Nor do these figures refer to tiny crystals that are best scrutinized with a magnifying glass. The minimum commercially usable cross section is about one inch square, with production bars closer to two inches square and nine inches long. Crystals a foot long have been produced.

As Dr. Albert C. Walker, '18, explains in the October issue of the *Bell Laboratories Record*, crystal culture calls for patience and precision. Starting with a "seed" crystal, which is usually a good sized slab cut at the proper orientation from a previously grown crystal, it may take a month to grow a unit of commercial size, the temperature of the solution having dropped continuously a fraction of a degree per day throughout this period. In the large rooms where the crystals are grown, thousands at a time, the controls must be able to produce a required temperature held constant to 0.1 degree C. Since the solutions are supersaturated, they not only deposit on the growing faces of the seed crystals, they tend to start small and unwanted crystals all over the tank. Forcing the rate of growth exaggerates this trouble and also causes cloudy areas to be produced in the crystal.

Although these crystals are grown from solution, they bring to mind an earlier development in which M.I.T. played an active part which has also become a small industry. That is the production of a wide variety of crystals from their melts, in sizes which, by natural standards, can only be termed immense. Whereas the crystals previously enumerated are used almost without exception for their piezoelectric effects, the latter are generally utilized for optical purposes. Among the more widely used salts of this type are lithium fluoride, important for its excellent transmission of ultraviolet rays, and potassium bromide, desired for lenses and prisms in infrared spectroscopes.

In the 1930's Dr. Donald C. Stockbarger, '19, Associate Professor of Physics at M.I.T., developed a technique for growing crystals of lithium fluoride. He used two tubular vertical furnaces, one on top of the other, placing between them an annular baffle that created a localized and steep temperature gradient. The melt freezes into a single crystal as it is lowered through this gradient. The salts must be kept free of impurities and foreign particles, or the resulting crystal will be cloudy, discolored, or distorted. Such defects occur frequently in the natural product, as well as in synthetically grown crystals, and render the crystals unsuitable for optical use.

Roentgen Rays against Cancer

Research in the Generation of Multimillion-Volt X-rays and Improved Clinical Techniques Marks Recent Progress in Treatment of Deep Malignant Tumors

By John G. Trump

THE disease to which Hippocrates in the Fourth Century B.C. applied the enigmatic and disquieting name of "cancer" is now for the first time marked for open battle by the combined forces of science, medicine, and enlightened public opinion. Cancer has made a vivid and fearful impression upon the human mind since antiquity. The earliest account of some of its clinical symptoms is recorded in an Egyptian papyrus of the Fifteenth Century B.C. Many observations of its nature had been made by the end of the Hippocratian era, and further accurate classification of the disease was accomplished in 150 A.D. by Galen, whose principles persisted until the Nineteenth Century. Today the ultimate nature and causes of cancer are still largely a riddle, but knowledge of its almost infinite manifestations and factors affecting them is steadily advancing. While cancer the disease is growing in social importance, the successes in cancer research and therapy have been many and can now occasionally offer hope of complete clinical cure. In this battle against the most mysterious and baffling of human diseases, the armamentarium of humanity includes the techniques of the physicist, chemist, geneticist, biologist, bacteriologist, as well as the internist, surgeon, and radiologist. Most recently, because of the critical need for early diagnosis and enlightened response, the general public is being awakened to its necessary role in this developing conflict.

Among the civilized countries of the world, cancer is now definitely second only to the diseases of the heart as a cause of death. In the United States about 175,000 people die annually of this disease. More than one in ten, about equally divided between men and women, are destined to die of cancer. The apparent rise through the years in the incidence of this disease is undoubtedly due to improved diagnosis and to the increasing age of populations, for cancer preferentially strikes those of middle and advanced age, although certain types, such as embryonal tumors, are more common in early life. Several hundred varieties of malignant tumors are now recognized, and their characteristic development has been the subject of clinical observation for many years. More important, fundamental processes in the origin of cancer and its control are the subject of intensive research. The genetic factor in the incidence of cancer has been studied in both men and animals, as well as the carcinogenic effect of mechanical irritation, of certain chemical compounds, of bacteria, of viruses, and of exposure to radiation. The study of transplantable tumors and the factors contributing to the development of the graft or the maintenance of immunity, the possibilities of ionizing radiation to inhibit the growth or to destroy malignant tissue, the use of hormone and certain chemical inhibitors, and a host of other types of fundamental biologic, physical, and clinical research are throwing light on the basic problem of cancer.

Two Accepted Forms of Cancer Therapy

Even with this long background of intensive investigation, the only two accepted methods of treatment for cancer are surgery and radiation therapy. With few scattered exceptions, it is only by completely exorcising the malignant tumor or by removing it *in situ* with cell-destroying radiations that this disease can now be

Pioneering work in radiation therapy with x-rays produced by over one million volts was made possible by the M.I.T. designed air-insulated electrostatic generator at the Huntington Memorial Hospital. More than 1,000 patients have been treated with this unusual equipment which established many of the advantages of supervoltage radiation for deep cancer therapy.

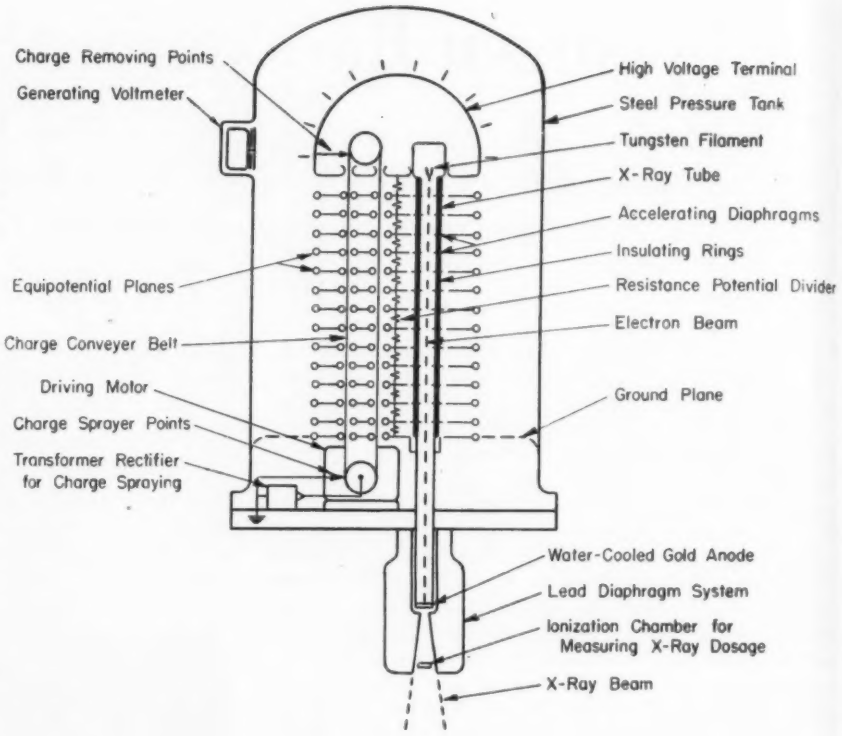


Diagram of an electrostatic x-ray generator. Following the original suggestion of R. J. Van de Graaff, electric charge is transferred to the high-voltage terminal at a continuous rate by a belt of insulating material. This charge maintains the terminal at a steady negative potential with respect to ground, and supplies the electrons required by the acceleration tube. Both tube and belt are mounted within the insulating column which is especially designed to insure a uniform voltage distribution between terminal and the ground plane. Electrons emitted from the hot tungsten filament at the high potential end of the tube are progressively accelerated and focused as they pass along the acceleration tube and thus acquire the full potential of the terminal. On impact with the water-cooled gold anode, the kinetic energy of the electrons is transferred into penetrating radiant energy. Since this radiation is emitted in all directions, a lead diaphragm system is used to absorb the unwanted radiation and to define the beam of ionizing radiation used in therapy. Except for the interior of the highly evacuated x-ray tube, the entire apparatus is insulated by compressed gas at a pressure of 27 atmospheres. It is this feature which permits these instruments to be built with unusual compactness.

controlled or eliminated. Both these techniques, often used in combination, have resulted in thousands of clinical cures, particularly in the case of superficial malignancies or in deep tumors detected in their early stages. Both these techniques have improved steadily with time. The former has progressed because of the increasing skill of the surgeon and the anesthetist and their techniques now permit the removal of new growths from nearly any organ or tissue of the body. The latter has depended upon the development of new and more effective forms of radiation intelligently employed by the radiologist. Cancer of the lip, mouth, larynx, uterus, and bladder is often treated by radiation alone. In addition, radiation plays an indispensable role in combination with surgery for the control of many other types of malignant tumors. It is in the field of radiation therapy that significant contributions have been made by the research groups at M.I.T., where engineering, physical, and clinical research on cancer has been in progress for more than a decade.

Supervoltage Roentgen-Ray Treatment

The problem of the radiologist is to deliver to the malignant tumor such a quantity of ionizing radiation as to effect its gradual, but complete destruction while causing only a tolerable injury to surrounding healthy tissue. Particularly in the treatment of deep tumors and those concerned with vital organs has the use of penetrating and ionizing radiation been indispensable. Within a few months of Roentgen's discovery the therapeutic, as well as the diagnostic, value of x-rays had been noted, and x-rays were being employed for the treatment of superficial lesions. A few years later, Madame Curie's brilliant isolation of radium, whose products emit a similar but far more penetrating radiation, added another powerful tool for therapy. During the next 50 years the relatively low-voltage and easily absorbed roentgen rays available to Roentgen's medical confreres have been gradually increased to about 250 kilovolt radiation for the deep-therapy application. The limited amount of radium is used to an increasing extent only in direct application to accessible tumors — those on the surface or accessible through the body orifices. In interstitial therapy the gamma-ray emitting needles or seeds are inserted into the tumor mass. Deep tumors, the most serious clinical problem, are now universally irradiated with roentgen rays in the 250-kilovolt energy range, assisted in certain cases by gamma-ray irradiation.

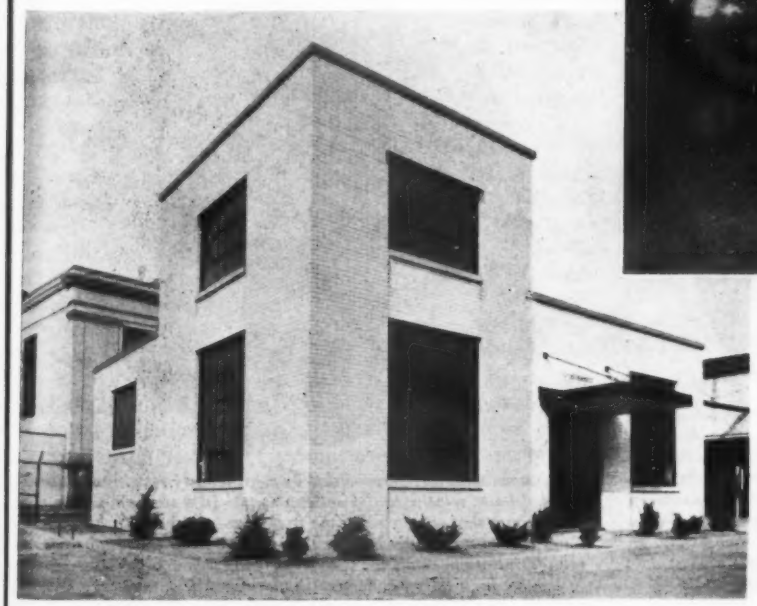
That higher voltages would produce a superior quality of radiation for deep therapy has been appreciated for many years. During the last decade, however, less than a dozen clinical institutions in the world have had available x-ray sources operating in the vicinity of one million volts. Dr. Robert S. Stone of the University Hospital in San Francisco has treated patients since 1935 with million-volt radiation produced by the ingenious high-frequency Sloan generator now obsolete because of its complexity. In 1937 Dr. Richard Dresser of Harvard's Huntington Memorial Hospital in Boston began the first constant-potential x-ray treatments with the M.I.T. air-insulated electrostatic generator operating at slightly more than one million volts. This was followed by the Massachusetts General Hospital program in 1940, under Dr. George W. Holmes and now Dr. Laurence L. Robbins, using M.I.T.'s one-and-a-quarter-million-volt pressure-insulated generator. At the St. Bartholomew's Hospital in London clinical treatments were begun by Dr. Ralph Phillips in 1937 at 700 kilovolts, and the large transformer-rectifier apparatus was gradually improved to million-volt operation. The Memorial Hospital in New

York has used General Electric's million-volt resonance transformer for x-ray therapy for about 10 years. In Norway, Dr. S. N. Bakke of the Municipal Hospital, Haukeland, Bergen, began treatments in 1942 with a one-and-a-half-million-volt air-insulated electrostatic generator designed by Odd Dahl, formerly of the Carnegie Institution of Washington. A number of other programs at intermediate voltages could be mentioned. All have reported with varying degrees of enthusiasm the observation that certain more favorable therapeutic reactions could definitely be ascribed to the higher voltages at which the x-rays were generated.

Radiation Therapy at Two and Three Million Volts

Since January, 1946, in a clinical therapy program under the medical direction of Dr. Richard Dresser, patients have been treated on the grounds of M.I.T. with roentgen radiation produced by an electrostatic research generator which can operate at well over three million volts. In the ensuing 18 months, complete treatment series were given to more than 150 selected patients. After interruption during the summer of 1947 this clinical program will be resumed with a larger clinic and improved, higher-voltage apparatus. Roentgen radiation produced by three million volts exceeds in quality the gamma rays from radium in equilibrium with its decay products. The output intensity of this therapeutic generator is several times greater than the combined radiation output of the entire world supply of this precious material. This roentgen-ray source operates at the highest voltages thus far clinically used in cancer therapy. The preliminary observations made in the course of the work have generally confirmed the physical evidence that roentgen rays of several million volts of energy are superior in certain important respects to the relatively low-energy radiation now in common use and even considerably better than the one-million-volt radiation investigated over the last decade. That extensive clinical research by many investigators will be required to exploit fully the therapeutic qualities of these high-energy radiations is also evident; several years of physical and clinical research will be needed to consolidate the benefits derived from higher voltages.

The supervoltage x-ray source located in a small building on Institute property near Vassar Street in Cambridge is a pressure-insulated electrostatic generator of the type first developed by Robert J. Van de Graaff. Designed by the electrical engineering group in 1940 for physical and medical research, it was applied during World War II to the irradiation of atomic pile materials with intense ionizing radiations and also served as a prototype for the electrostatic generators developed at M.I.T. for military radiography. Now, reapplied to peaceful pursuits, high priority is given to the daily medical program, but the unusual quality and quantity of ionizing radiation produced by this equipment is also of interest in other investigations. In a co-operative study with the Department of Food Technology, the biological and photochemical effects of both x-rays and cathode rays on micro-organisms and on food and drug products are being studied. In another aspect of this program the physical properties of these radiations and their action on nonliving matter are actively followed.



(Above): *The column and terminal structure of the three-million-volt generator at M.I.T. with its tank removed. This generator produces voltages over 10 times higher than the standard voltage for deep x-ray therapy. Its radiation output, more penetrating than gamma rays of radium, is equivalent to several times the total world supply of that precious material.*

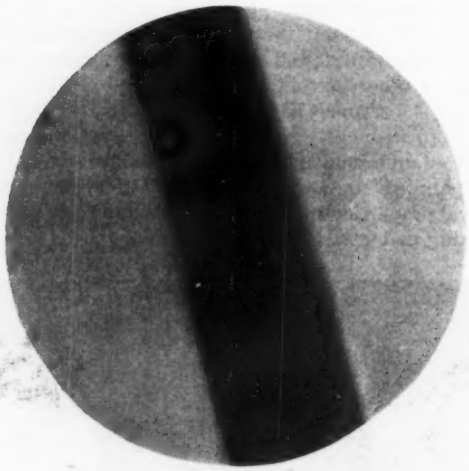
(Left): *Exterior of the Hyams Building which houses the three-million-volt x-ray and cathode-ray generator used in clinical research at M.I.T.*

An important therapeutic property of these supervoltage roentgen rays is the unusually high skin tolerance which almost completely eliminates skin damage in the treatment of deep tumors. In the past, x-ray therapy has suffered from the limitation that the radiation must enter through the relatively radiosensitive skin and undergo very considerable attenuation and misdirection by the absorption and scattering processes before it reaches the site of a deep tumor. Many of these difficulties are reduced by the skill of the radiologist in the choice of treatment distance, field size, number of portals through which the radiation is directed, and fractionation technique by which he distributes the total dose over a period of days or weeks. More often than not, however, in the present treatment of deep-seated malignancies, the tumor dose is established not by the optimum amount required to destroy the tumor, but rather by the tolerance of the surrounding normal tissue and skin through which the radiation must pass. Most deep tumors treated with 200-kilovolt radiation can be reduced, if at all, only by doses which produce a violent skin reaction and the absorption of sufficient ionizing energy by the patient to produce nausea and other physiological disturbances. In the clinical program at M.I.T. it was found that both of these difficulties have almost entirely disappeared. Doses have been delivered to the site of a deep tumor sufficient to cause its regression with only mild skin erythema or no skin reaction at all. Patients have been treated for abdominal tumors with little or no systemic reaction. Clearly the possibility has been developed for the first time of delivering to a deep tumor a dose defined primarily by the requirements at the tumor site rather than the tolerance of intervening tissue.

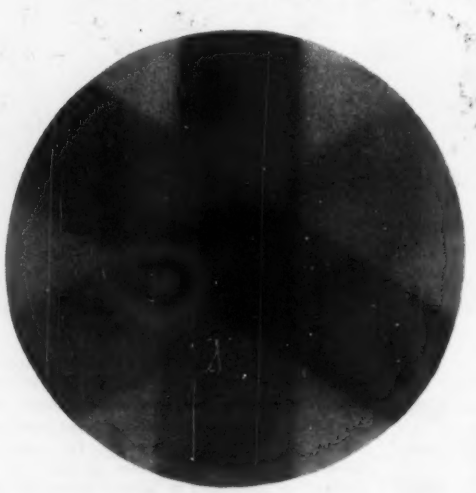
A second advantageous property for deep therapy of supervoltage roentgen rays is the substantial increase in penetration of the radiation beam. For a given dose sustained in the region of the skin, three-million-volt rays will deliver twice as much ionization energy to a tumor at a depth of 10 centimeters as will 200-kilovolt rays. As a result, deep tumors can be much more efficiently irradiated with less damage to surrounding healthy structures and less total ionizing energy absorbed within the body of the patient.

Radiologists have often employed the "cross-firing" technique as a means of delivering a high tumor dose with a minimum of external skin damage. In such procedure the tumor is irradiated from several directions so that the dose is cumulative in the tumor, but distributed

The three circular radiographs illustrate the technique of cross firing with one, three, and continuous-portal radiation, as described under each of the separate illustrations.



A two-million-volt beam of x-rays passing through a 20-centimeter cylinder of Masonite representing a phantom patient. In deep x-ray therapy the beam of radiation must enter through the skin and pass through the intervening healthy tissue before it reaches the tumor itself. Supervoltage x-rays produce relatively little reaction on the radiation-sensitive skin, and because of the higher penetration and lower scattering, are capable of delivering a higher dose to a deep tumor than can be achieved with lower-voltage x-rays.



Deep tumor doses can be augmented by cross-firing technique in which the radiation is directed at the tumor from several directions as shown by the dark strips. In the three-portal cross-firing technique the radiation is directed at the tumor from three different angles as shown here. In this case the tumor dose is 60 per cent higher than the highest dose sustained outside the selected tumor region.

Continuous cross firing, produced by continuously rotating the tumor-directed beam relative to the patient, results in a uniform tumor dose many times that sustained by the radiation-sensitive skin and several times that sustained by healthy tissue adjacent to the tumor. Supervoltage radiation, combined with cross-firing technique, makes possible high efficiency in treating localized deep tumors.

This supervoltage x-ray generator, the most compact machine thus far developed for cancer therapy, is comparable in size and flexibility of use to lower-voltage equipment now generally available. It was developed at M.I.T. under a grant by the American Oncologic Hospital which will use it in its program of deep therapy.

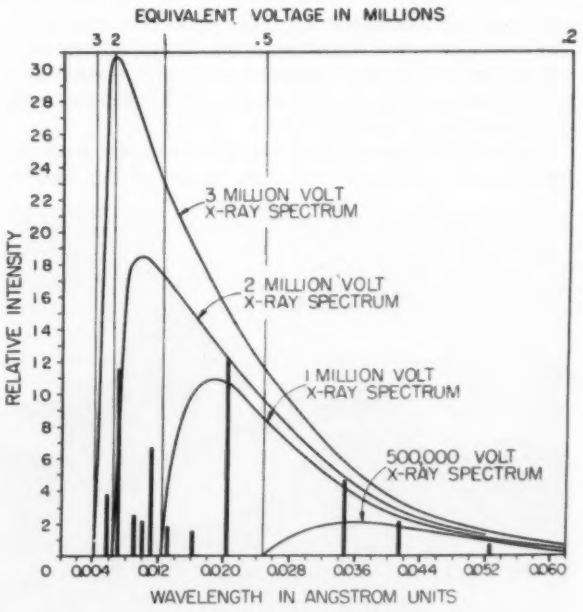
in the surrounding healthy tissue and skin. When this technique is likewise applied with supervoltages, unusual selectivity of radiation dose is accomplished. Cross-firing from three directions results in a deep tumor dose which is greater than the highest dose sustained elsewhere in the tissue. Using a continuous cross-firing technique with supervoltage rays, it becomes possible to deliver to a localized deep tumor dosages which are six times higher than those absorbed by even nearby healthy tissue. Thus the dream of the radiologist of delivering to arbitrarily selected regions deep within the body cell-destroying ionization far greater than that sustained in other regions becomes attainable.

Unfortunately the clinical problem is often more complicated. Deep-seated malignancies may not be well defined. Tumors of the bladder, uterus, larynx, and thorax are often localized, whereas other common cancer types are likely to have nearby or distant extensions from the primary tumor site. Metastasis from the primary tumor along the lymph nodes is a common characteristic which requires that these distributed regions of possible malignancy must be found and destroyed. The probable areas where metastasis might occur are often fairly definitely known from clinical experience so that preventive radiation therapy may be initiated even before symptoms appear. It is perhaps even more important to treat effectively the periphery of malignant regions and their actual or anticipated metastases than to concentrate on the primary tumor. Although this clinical problem is more complicated, the use of more penetrating, less scattering, and more skin-favoring supervoltage radiation, combined with real diagnostic and radiologic skill, should pay dividends in increased comfort and life of the patient.

High-Voltage Research at M.I.T.

The present medical work with supervoltage x-rays is an outgrowth of a development program for nuclear research which began at M.I.T. in 1932. At that time Robert J. Van de Graaff, then just removed from Princeton where he had developed the electrostatic principle of voltage generation for which he is acclaimed, was constructing the large air-insulated electrostatic generators at Round Hill, New Bedford, for nuclear research. Within the Department of Electrical Engineering investigations were beginning on the insulation of electrostatic generators in high vacuum and on the possibility of developing more compact sources of high constant potentials.

Today the original Round Hill generator, moved to a steel building on the Institute's property in Cambridge, is in continuous use in nuclear studies with electrons or positive ions of two-million-volts energy. The steady stream of charged particles produced by the electrostatic accelerator is homogeneous and accurately controllable in energy and free from extraneous background radiation. These characteristics are virtually indispensable in certain important precision studies of nuclear structure and are not attained in the cyclotron, betatron, synchrotron, or other indirect particle-accelerators which are inherently capable of far greater energies. A new compressed insulated generator (*Continued on page 122*)



When high-energy electrons are stopped on impact with a gold target, their kinetic energy is converted into penetrating electromagnetic radiation. The effect of increasing the voltage is to move the continuous x-ray spectrum in the direction of shorter wavelengths and to increase efficiency of x-ray production. The curves show that the spectrum of three-million-volt x-rays includes wavelengths shorter than those emitted by radium in equilibrium with its products, as shown by the line spectrum. Such radiation is, therefore, superior to radium in its penetrating, nonscattering properties.

How Long Will Our Metals Last?

The World's Supply of Metals, Definitely Not Inexhaustible, Can Be Prolonged by International Co-operation, Aided by Conservation and Research

By Carle R. Hayward

MANKIND had its Stone Age when it adapted this omnipresent material to various purposes in advancing the standards of living. Then came the Bronze Age in which easily reduced and fabricated nonferrous metals were used to replace stone and wood and for many new purposes. Thus civilization was still further advanced. Utilization of metals has increased as civilization progressed until some stocks show signs of early depletion and we may well ask, "How long will our metals last?" To answer this question we need to examine the uses to which metals have been put in the past, to survey our present consumption, and to extrapolate, as well as we can, into the future. We begin this survey with the most common metal — iron.

Iron is seldom found in the metallic state and then only in alloys of probable meteoric origin. Because it is less easy to reduce and fabricate than copper, it came into general use long after men had acquired crude metallurgical skill in reducing copper and other nonferrous metals.

Iron is one of the most abundant elements in the earth's crust and after methods for reducing and fabricating it had been discovered this abundance stimulated increased use and improvement in techniques, thus making it possible to lower the cost simultaneously with improvement in the quality of the product.

These improvements have continued actively until the present day with the result that the use of iron and its alloys has become one of the most important factors in the development of modern civilization. The total tonnage of all nonferrous metals combined is less than 10 per cent of the iron and steel tonnage. This is due primarily to the relatively low cost of iron and steel combined with intrinsically valuable properties and there seems to be no reason to believe that this wide margin of leadership among the metals will be seriously altered for many decades, if ever.

In early colonial times furnaces for the reduction of iron ore sprang up wherever ore occurred sufficiently close to a settlement to produce a demand. The ore used was commonly the limonite known as "bog ore"; a material which is low in iron and high in silica. It occurs in relatively small shallow deposits and is not used today. The early furnaces were small and used charcoal for fuel. The output per man-hour and per furnace day was small and the produce was impure; yet it played an important part in colonial economy. Among the active furnaces in the Massachusetts Bay Colony were those at Saugus and Braintree, and in the Plymouth Colony, at Bridgewater, but several others operated for a time.

The magnetite deposits along the Appalachian Range furnished a richer ore than the bog deposits and became important as colonization proceeded westward. Remains of some of these furnaces in various states of repair or restoration exist at several points. One of these at Corn-

This iron blast furnace at Cornwall, Pa., gives some idea of colonial facilities for producing metal. Built in 1742 and enlarged in 1845, the enlarged furnace had a capacity of 20 tons of iron per week when it ceased operation in 1883. Wing at right contains blowing engine; left wing covers casting floor. Furnace stack is in the center.

Photo, Bethlehem Steel Company

wall, Pa., which furnished metal to equip the Revolutionary forces of General Washington is especially well cared for. It was supplied with ore from a neighboring mine which is still being actively operated by its present owner, the Bethlehem Steel Company.

There is an interesting story about this mine which illustrates the difficulty in making accurate predictions regarding the life and development of mineral deposits. It seems that an early owner who considered the property inexhaustible gave a friend written permission to take from the mine enough ore to supply one furnace "as long as grass grows and water flows." Ownership of the mine and the written permission changed hands several times during the next 150 years and the size of the "one furnace" increased from five or six tons of product to over 100 times that figure. Successive owners of the mine made frequent attempts to buy off the successive owners of the paper but it was not until about 1930 that they came to terms and a cause of serious friction was removed.

Colonization moved westward and in due course other important iron deposits were discovered and developed, notably those in Michigan, Minnesota, and Alabama. The vicissitudes connected with the discovery and exploiting of the great deposits of Minnesota are well described by Paul de Kruif in *Seven Iron Men*.[1] Two great wars and increasing demands of industry have made heavy inroads on these deposits and lines of worry are evident on the brows of officials of steel companies which are dependent on them. Attention is being turned to areas in Canada contiguous to the mines in the United States and properties in Cuba, South America, and Africa are becoming of increasing interest.

Many predictions have been made regarding the probable life of the Michigan and Minnesota mines which supply such a large part of the needs of this country. Some writers, in panic, say the best ore will be all gone in less than 25 years and others more optimistically double the figure but all agree that the high-grade ore will be completely exhausted in the lifetime of men now living. This is something of vital interest to every inhabitant of the country. Where can we get more iron ore and what if anything can we do to prolong the life of our deposits?

As stated above, several United States companies are acquiring interests in, and actively developing, foreign mines but even these will supply our needs for high-grade ore for only a generation or two. We must not forget however that modern methods for geophysical prospecting, assisted by the use of helicopters to land parties in regions of the earth hitherto nearly inaccessible, may bring about discoveries of iron ore and other mineral deposits in places where they have not been suspected.

The above statement may be discarded by some as mere wishful thinking so it is well to consider other solutions to the problem.

The great hope of the world in extending the life of mineral deposits lies in the field of mineral dressing. The late Professor Robert H. Richards, '68, was a pioneer in this field. At his own expense he carried out extensive fundamental research in the gravity concentration of minerals and his published results were eagerly studied by workers in other laboratories. Men trained in ore concentration at M.I.T. made their mark in many parts of this and other countries. Concentration by flotation was just coming on the scene as Richards was passing off and it has now become the most important method for the concentration and separation of minerals. As the fundamental scientific laws governing it are becoming more fully understood, the selectivity of the operations is being improved, and this in turn makes it possible to start with a very low-grade ore and produce economically a high-grade concentrate which can easily be converted to metal or into uses as a valuable nonmetallic material.

[1] New York: Harcourt, Brace and Company, 1929, $3.00.

Photo, Kurt Severin of Black Star

Contrasted to the blast furnace on the opposite page is this modern Goliath of the Ford Motor Company whose output dwindles to insignificance the production of 20 tons per week achieved by the Cornwall furnace.

Mineral dressing grew up at M.I.T. in the Mining Engineering Department and was happily retained when this Department was abolished. It is still functioning energetically, principally in the field of flotation, under the direction of Dr. Antoine M. Gaudin.

As one example of what mineral dressing can do, reference will again be made to the Cornwall mine in Pennsylvania. The early operators were bothered by the presence of sulfur and copper in this ore and since the iron was in the form of magnetite a continuous method was first developed for separating the magnetic iron mineral from nonmagnetic sulfide and silicate minerals. Partly with the advice and help of Professor Richards and other M.I.T. graduates the nonmagnetic product was separated into a marketable copper-bearing sulfide product and siliceous waste. Later when development of flotation made the separation of sulfide minerals practicable a further separation was made of the copper mineral chalcopyrite from the iron sulfide, pyrite. It was then found that cobalt, which was known to be present as a small fraction of one per cent in the ore, was all carried by the pyrite and a process was developed for extracting it profitably from this cobalt-enriched product.

The Cornwall ore is a special case but mineral dressing

Photo, Ewing Galloway

Plying the Great Lakes with their valuable cargo of iron ore are freighters, such as that shown here, with hatches especially constructed to load and unload ore quickly.

in various combinations of the older gravity and magnetic methods with constantly improving flotation procedures is being increasingly used to treat low-grade iron ores and make a product suitable for blast furnace smelting.

Although it is possible for a blast furnace to smelt a relatively low-grade ore and produce a small amount of good pig iron it is obvious that as long as high-grade (above 50 per cent iron) material is available, giving a larger iron output per furnace day, the low-grade material cannot be treated economically in comparison with it. Enormous amounts of low-grade material are available and it is fair to predict that with the help of mineral dressing the blast furnace plants can be supplied with high-grade concentrates long after the natural high-grade deposits are exhausted.

If the time comes when the blast furnace operators cannot get the kind of material they now think necessary, they can use a lower grade raw material and still give us iron but at slightly higher cost based on present knowledge. It is not unreasonable to hope and expect, however, that improvements in methods for converting ore to steel will make a contribution to the extension of our iron resources by cutting smelting costs. The use of cheap oxygen[2] may well have an important effect in making this possible.

A further combination of factors has had continuing influence on the conservation of iron resources and its influence may become more pronounced in the future. Reference is made to increasing knowledge of the structure of steel and how to bring about, by alloying and heat treatment, the properties desired. Testing the strength of materials and increased knowledge of the causes of failure also come into the picture and it is now possible to specify accurately the kind of material and the shape and cross sections of a steel member for almost any structure.

To illustrate the above fact attention is called to the first Brooklyn Bridge.[3] In this case, lack of knowledge of strength of materials and bridge design required the use of factors of safety so large that many decades later the bridge was able to bear a weight of traffic wholly undreamed of at the time it was built. This may have proved to be a blessing in disguise but shows how conditions have changed.

A further factor in conserving our iron resources is the increasing care used to minimize corrosion. We are continually hearing more about the causes of corrosion and are developing methods for reducing its ravages. The life of iron and steel structures is thus prolonged and the amount of the original structure finally returned to be reworked as scrap is considerably increased.

The International Nickel Company reports that a building had an ornamental spire 16 feet high and weighing 8,000 pounds made of ordinary carbon steel. After serious corrosion it was replaced by a stainless steel spire weighing 1,000 pounds.

One factor in keeping down the cost of iron and steel is worthy of mention. This is the mechanical handling of materials from mine to finished product. Long trains of hopper bottom cars are loaded by great steam or electric shovels in the open cut mines of Minnesota, drawn to specially constructed ore docks from which specially designed boats are quickly loaded by gravity. After passing through the lakes the boats are quickly emptied by specially designed buckets of large capacity which discharge on ore docks at a blast-furnace plant or into cars for transportation overland.

At the furnace plants the greatest engineering skill has been devoted to the design of equipment and its efficient operation, all of which is reflected in the final cost of finished product.

The inevitable conclusion to be drawn regarding iron is that it will continue to be the most widely used of the metals even though, for some purposes, it may be replaced on a competitive basis by other materials.

Copper

Copper is the most widely used of the nonferrous metals. It is exceeded only by silver in electrical conductivity and for this reason its principal use is in the electrical industry. It is also the principal constituent in such widely used industrial alloys as brass and bronze. Its high resistance to atmospheric corrosion results in important uses in the building industry.

For more than 60 years the United States has been the world's leading copper producer. In 1929 it produced nearly one half of the world output, and nearly half of the United States production came from the state of Arizona. The great mines of Michigan, where the copper uniquely occurs wholly in the metallic state, are nearing exhaustion and other former great producers, such as the United Verde mines of Arizona and various other great mines are either closed or about to close. There has been some concern over the depletion of the ore at Butte, Mont., known

[2] Stevenson, Earl P., "Oxygen for Industry," The Technology Review, November, 1947, p. 32.

[3] Cameron, Edward H., "High Road to Brooklyn," The Technology Review, May, 1946, p. 419; June, 1946, p. 487.

as "the richest hill on earth" but the president of the Anaconda Copper Mining Company has recently announced that intensive exploration, coupled with improved mining and concentration methods, will extend the life of the deposit for many years. The development of new properties and improvement in extraction techniques have thus far kept the United States self-sustaining but it may not remain long in that class.

Mineral dressing has thus far been even more important in the copper industry than it has in the iron and steel industry. In fact the cost of copper would be prohibitive without it. It has made possible the development of such mines as that of the Utah Copper Company near Salt Lake City where, at peak production, more than 80,000 tons of ore are mined per day and in the process of treatment it is all crushed to about the fineness of table salt. This ore contains only one per cent of copper yet the operations have been so skillfully developed and integrated that the mine has been highly profitable and the flotation mills have sent the smelter a very satisfactory, economical concentrate.

For many years it was considered that ore with a copper content of about one per cent was as low as could be mined and treated at a profit. Copper prices are now higher and efficiency of treatment is also higher. There is a probability that a very large deposit containing only 0.8 per cent copper will be opened up soon — which is another illustration of how available resources are expanded as technical skill increases and an advance in price stimulates production.

The cost of producing copper was kept low for 25 years in the face of many factors which tended to increase it by raising the capacity of the furnaces used for smelting copper concentrates without greatly changing their major dimensions. The huge demand for copper in World War I stimulated changes in furnace design and firing technique which doubled the copper output. In the 1920's improvement in concentration methods gave the furnace operators a charge with about twice the copper content it formerly had and further improvements in furnace operation have increased smelting rates so that today, with no change in size, a furnace can turn out about five times as much copper as it could produce under conditions existing in 1915 with but little more labor and fuel.

In all this progress M.I.T. men have played an important role. The rapid spread of the Institute's fame throughout the West and into foreign countries, particularly in the early days of its history, was due in no small degree to its graduates in mining and metallurgy who went pioneering into remote places. In more recent years, even with increasing competition from other excellent schools, the accomplishments of M.I.T. Alumni have continued to be highly creditable.

Although the United States may soon cease to be self-sustaining in copper the world outlook is not too alarming. The situation is, however, less satisfactory than is the case with iron and the time is not far distant when demand will begin to exceed supply and prices will rise. If no new sources become available to keep prices down, various substitutes will come increasingly into use. The most promising competitor of copper is aluminum.

Aluminum

Aluminum is one of the most abundant materials in the earth's crust, estimates making it slightly greater than iron by weight. Also, like iron, considerable quantities

Photo, Kennecott Copper Company

A modern electric shovel replaces the man power of earlier days in loading flat cars in a copper mine in Nevada. In one bite the shovel accomplishes as much as a score of men.

exist as relatively high-grade oxide deposits with an abundance of lower-grade oxides and complex silicates.

Up to the present time only one process has been developed for producing metallic aluminum from its ores. This process involves two steps, the first of which has for its objective the production of substantially pure aluminum oxide, and the second the reduction of the purified oxide to metal. The only commercially successful reduction process requires large quantities of electric power to electrolyze the metal from a bath of fused fluorides in which the aluminum oxide has been dissolved.

Lower power costs, improved processes for producing purified oxides, the increase in demand, improved techniques, and the growth of some competition in the industry have all combined to gradually cut the cost of producing aluminum until today it sells for little more than half the price which obtained 20 years ago. An abundance of low-grade, raw material is available and will ultimately be used but at present it is more economical to use the more easily worked high-grade ores.

Aluminum is a versatile metal and its use is rapidly expanding. Some plants are now fabricating it into structural members and sheets on a scale comparable with that used in steel plants and the saving in fabricating costs thus achieved has made aluminum attractive for many purposes. Its intrinsic lightness is causing it to be specified in preference to steel and other metals in vehicles and for certain uses in the building industry.

Regardless of improvements and new discoveries in reducing metals from ores there are fundamental reasons why it is only in cases where its special properties outweigh the initial cost that aluminum will replace steel.

Photo, Kennecott Copper Company

Mining operations at the Ruth Copper Mine in Nevada bear a peculiar likeness to the terraced fields in contour farming.

Magnesium

The use of magnesium had been slowly increasing between World War I and World War II but it was distinctly a minor metal used only where its extreme lightness made it attractive. Its mechanical properties in the pure state are not all that could be desired and only a few alloys have thus far been developed which are as desirable as some of the aluminum alloys. However, the production of magnesium and its alloys had a phenomenal growth during World War II for two general uses, namely, incendiary bombs and aircraft parts. Since the war the first use has stopped and the second has been greatly curtailed.

No long distance survey of metals can ignore the potential possibilities of magnesium. It is the lightest of the more abundant metals and the world is definitely becoming light-metal conscious. Lightness is a distinct asset, especially when a body is to be propelled at high speed. When magnesium and its alloys have received the benefit of as much research as has been lavished on aluminum, it is highly probable that their properties will be greatly improved and their uses expanded.

In evaluating the future of magnesium, attention should be called to the fact that considerable quantities have been produced economically from sea water. Regardless of size, therefore, every country in the world with a sea coast has a never failing source of magnesium. If such countries have also a large and cheap source of electric power they can produce the metal in unlimited quantities. This fact may become of great importance as time brings a partial exhaustion of other metals.

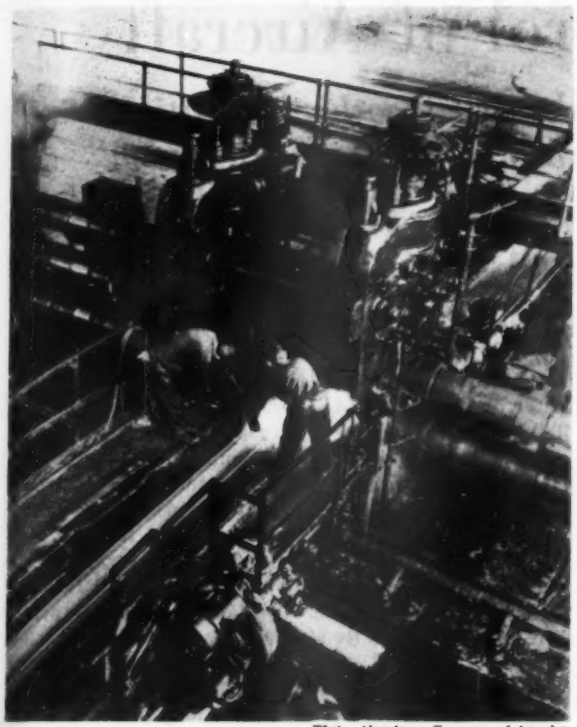
Just as aluminum is making a place for itself in world economy, because of its specific gravity, so it is reasonable to believe that magnesium, because of its even lower specific gravity and the ready availability of raw material, will be a metal to watch.

Lead

We will now jump from magnesium, the lightest of the common metals, and the most recent to come into large use, to lead which is the heaviest of the common metals and one which has been used extensively since the dawn of civilization.

The outlook for our lead resources is not good. No important new lead mines have been reported for any part of the world for many years and our old deposits are becoming sadly depleted. The United States has been leading all other countries in lead production for many years and we are fortunate in having nearby in Canada and Mexico two other large producers. Another large producer is Australia.

The principal uses of lead are for wet storage batteries, cable covering, pigments and in antiknock gasoline. The general situation became critical in the 1920's when the automotive industry was rapidly expanding and requiring increasing numbers of batteries, and the electrical industry was expanding and requiring more cables. The development of differential flotation greatly enhanced the production of lead concentrates from complex and hitherto economically unworkable ores and consumption was slowed during the depression. Strange to say, the demand for lead during the war, unlike that for many other metals,



Photo, Aluminum Company of America
The men are rolling a 12-inch aluminum channel in this three-high, 26-inch structural shape mill.

was not greatly accelerated but normal depletion has nevertheless continued to have a serious effect.

New deposits may be found and developed in the future but it is not safe to depend on it. We should study the uses of lead and curtail its use for purposes where it is finally wasted if we are to continue to have what we need for essential purposes.

Titanium oxide is rapidly coming to the front as an excellent substitute for lead in the paint industry and considerable quantities of zinc are also used. It is probable that if necessity demanded it, the versatile oil industry could find a substitute for lead as an antiknock agent.

Fortunately the lead used for battery plates is, to a considerable extent, recovered for re-use when worn-out plates are resmelted. To a lesser degree, the same is true of cable covering and to a much lesser extent in solder.

Considerable quantities of miscellaneous lead scrap are also recirculated and type metal is continually re-used with little deterioration. All these factors contribute to prolong the life of our lead deposits so if permanent wastage can be minimized the general outlook should be very greatly improved.

Zinc

Zinc is another of the major nonferrous metals, and, as in the case of the metals previously mentioned, the United States is the world's leading producer. It has numerous uses but the principal ones are in galvanizing iron and steel and as a constituent of brass. The development of differential flotation has an even greater effect on the output of zinc concentrates than it did with copper and lead. There was actually an overproduction in the late 1920's but the industry has leveled off and producers are looking with some apprehension at our diminishing resources. Formerly, large amounts of zinc were wasted in discarded slags produced in lead smelting. It is now becoming common practice to give the molten slag a further treatment in order to fume off and recover the zinc and incidentally most of the occluded lead which would otherwise be lost.

Although tin and cadmium are both used for coating iron and steel, the amounts so used are but a small fraction of the amount of zinc used for this purpose. Paints and other organic substances can be used to minimize corrosion but it would be difficult to find anything as satisfactory as zinc. It would be unfortunate if a world shortage should develop which would make zinc too expensive to use for this purpose. There is no immediate prospect of this happening but the life of known zinc properties is measurable in decades rather than centuries.

Precious and Minor Metals

The remaining metals which find a place in modern life are usually classed by the metallurgist under the two headings "precious metals" and "minor metals." The precious metals are gold, silver, and the platinum group. Compared with other metals they are scarce and costly.

Although gold resists atmospheric corrosion and acid attack, it is an interesting and highly important fact that it dissolves readily in cold water containing less than 0.1 per cent of sodium or potassium cyanide. This fact makes it possible to dissolve and recover gold profitably from finely crushed rock — a ton of which may contain only 0.1 ounce of gold.

The greatest use of gold for several hundred years has been as a basis for national currency throughout the world. Even though the gold standard has been legally abolished, gold is still looked to as a medium for settling international debts and thus retains its old status.

Tin is one of the well-known metals which has been found thus far only in insignificant amounts within continental United States. The most important source is in Southeast China and regions around the Malay Peninsula. The second important producer is Bolivia. Increasing amounts are also coming out of Africa. Production of tin is less than one-tenth that of copper.

The greatest uses for tin are for coating steel and for alloys, such as solder and bearing metal. Most of the coated steel is used for food containers and in spite of considerable research nothing as satisfactory for this purpose has thus far been found. Even so, if no tin were available or if the price becomes too high, certain lacquers will come in as substitutes. Electroplating processes for tinning steel were developed during the late war[4] which combined with subsequent annealing to seal minute breaks in the surface made it possible to produce satisfactory coatings with less than half the former weight of tin. This had an important effect in conserving our tin supply. A considerable recovery of tin is made from scrap-bearing metal and some by sweating solder from scrap-soldered materials. A minor recovery is also made by dissolving tin from scrap tin plates.

Nickel is another metal which is found to only a negligible extent in the United States ore deposits. Fortunately, however, the largest known deposit is located in the Canadian province of Ontario so our needs are easily supplied. The great use of nickel is in alloy steels where it improves the properties for (*Continued on page 116*)

[4] Whetzel, J. C., "Face Lifting for Tin Cans," The Technology Review, November, 1946, p. 37.

Automatic Control of Aircraft

Increased Reliability of Flying under All Weather Conditions and Reduction of Fatigue of Operating Personnel Are Some Features which Automatic Control Makes Possible

By Robert C. Seamans, Jr.

NEWSPAPER headlines recently recorded the first successful transatlantic round-trip flight of an airplane automatically controlled from the ground and sea stations. With many competent human pilots available, we may well ask what possible justification there may be for the huge expenditure of time and money which was required to accomplish this feat.

If we were to inspect a modern air liner, we would find the forward compartment of the airplane, used by the crew, to be an exceedingly complex aggregation of instruments and controls. Some of this complexity is to be expected for the flying of an airplane in three-dimensional space is much more involved than driving an automobile on what is essentially a two-dimensional plane. In front of the pilot's seat is a contrivance similar to the steering wheel of an automobile, except that it is mounted on an articulated column so that it can be rotated as well as pushed back and forth. The operation of this control wheel must be co-ordinated with the movement of foot pedals which control the rudder. In addition to the steering mechanism, there are perhaps 150 different buttons, switches, levers, and knobs, the proper operation of which constitutes a never ending challenge to the pilot's ability and skill. A button must be pressed when communicating with the airport tower for landing instructions. Landing lights must be switched on for a night approach. Levers are used to lower the landing gear and wing flaps. Throttles regulate the power output from the motors. So much detail is encountered in the flight of an airplane that a complete discussion of the many possible flight operations would fill a standard textbook.

The aircraft instruments, which are mounted in array on a panel in front of the pilot's control wheel, provide indispensable information for intelligent operation of the aircraft. Tachometers and other engine instruments are required, in addition to instruments for navigation, such as the magnetic compass, the artificial horizon, the altimeter, and the air-speed meter. The readings of more than 50 instruments must be analyzed by the pilot.

The difficulty of properly manipulating this complicated air-borne mechanism is accentuated by the speed with which significant events take place. Instrument observations must be made quickly, and there is little time for decision before effecting the correct control. The greater the accent on speed, the more difficult becomes the flying of an airplane. The latest jet fighter planes have been known to fly at 650 miles per hour, and when flying at this speed, the fighters travel the length of a football field in about one-third of a second.

The task of flying an aircraft for long periods of time has become too exhausting for one man. Today each commercial aircraft has a copilot to spell the pilot at intervals during the flight. A navigator equipped with all manner of celestial and radio aids informs the pilot of the correct course on long trips. A fourth member of the crew, the flight engineer, is important in all aircraft using four engines or more. He watches the fuel consumption, makes corrections necessary to account for unexpected head winds, and recommends the speed and altitude for optimum cruising conditions. Thus a system of checks and balances is established — with copilot, navigator, and flight engineer acting as a council for the pilot.

Even with a competent crew assisting the pilot, the reports of many recent accidents show that the proper operation of a modern airplane can demand more than human attention is capable of delivering. To help in this situation, special equipment is already in use, such as controls for holding engine speeds constant, and mech-

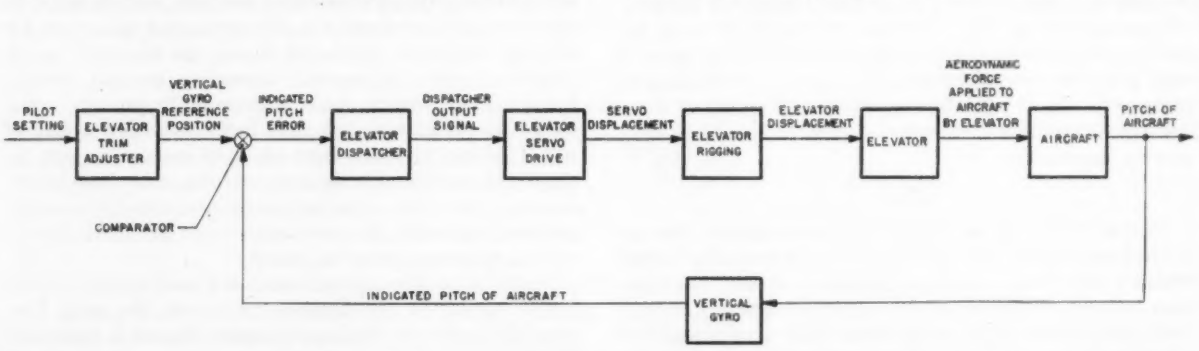
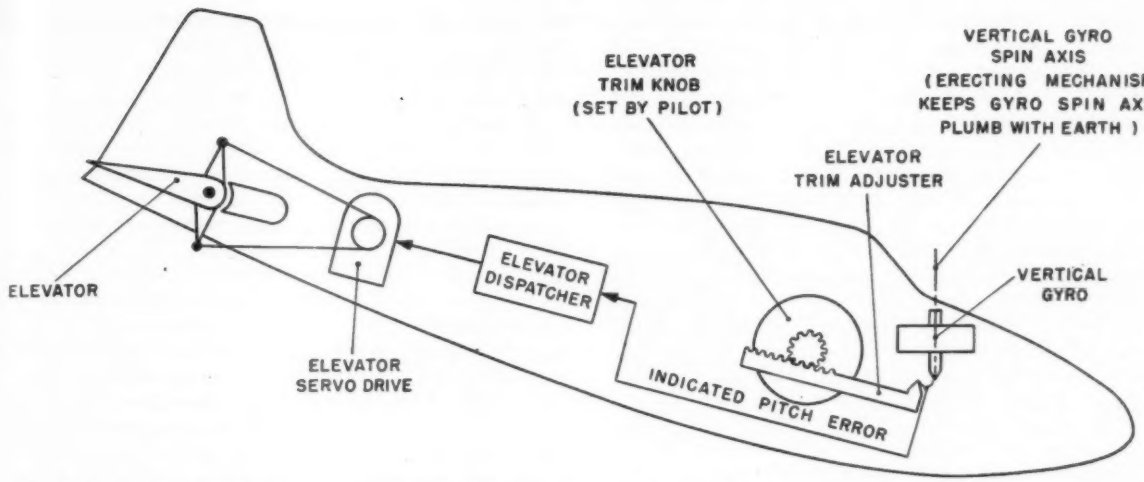
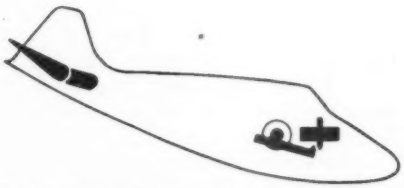


Fig. 1. Block diagram of functional elements in the automatic control of pitch of an airplane. The elevator trim adjuster enables the pilot to select a given elevation at which the plane will fly. The vertical gyroscope provides a directional reference standard against which the pitch of the aircraft may be compared. The difference between these two quantities, called the indicated pitch error, is the physical energy which is converted into a signal by the elevator dispatcher and which operates the elevator to bring the aircraft back on its predetermined pitch.



CONDITION 1 SHOWS THE AIRPLANE AFTER A GUST HAS FORCED ITS NOSE DOWN. AT THIS INSTANT AN INDICATED PITCH ERROR EXISTS BUT THE SERVO DRIVE HAS NOT HAD TIME TO DISPLACE THE ELEVATOR.



CONDITION 2 SHOWS THE AIRPLANE STILL IN A NOSE DOWN POSITION. THE ELEVATOR IS DISPLACED UPWARD BY THE SERVO DRIVE IN ORDER TO ROTATE THE AIRPLANE ABOUT ITS PITCH AXIS.

CONDITION 3 SHOWS THAT WHEN THE AIRPLANE IS AGAIN LEVEL, THE INDICATED PITCH ERROR IS MINIMIZED AND THE ELEVATOR IS BACK IN ITS NEUTRAL POSITION.

Fig. 2. Application of the closed loop diagram of Fig. 1 to the physical components of an airplane. The erecting mechanism of the vertical gyro maintains the gyro perpendicular to the earth's surface. Operation is indicated in the lettering on the diagram.

anisms to maintain constant the air pressure within the cabin. The most exacting equipment is used to direct the flight path of the airplane. This equipment automatically controls the heading of the aircraft and, while it is engaged, the pilot needs only to monitor the flight by the use of various instruments provided for this purpose. To maintain the intended direction of flight, the automatic control equipment must be able to detect divergence from the desired flight path and to actuate the control surfaces so as to minimize and correct for such divergence.

Weather is currently the bugaboo of both the air lines and the traveling public. The air lines are caught squarely on the horns of a dilemma, with the risk of accident counterbalanced by the need for revenue. The traveling public must gamble time saved in transit against time spent in a sit-down marathon in an air-line waiting room — in the latter event perhaps reinterpreting the fable of the tortoise and the hare. The full benefits will not be obtained from automatic control until additional refinements in design provide reliable all-weather flying. We may be confident that automatic control equipment will some day guide commercial airplanes through fog and snow as unerringly as a railroad track guides a train — but such a happy circumstance is for the future to fulfill.

Automatic control also makes possible certain special applications of aircraft in which any reasonable man would gladly forfeit his right to serve as pilot. When flying the newer type of aircraft near the velocity of sound, the pilot is risking his life on an engineer's extrapolation of current knowledge. The element of personal risk may be greatly reduced in such cases through the use of automatic control of aircraft, combined with remote-control devices which make possible the flying of newly designed aircraft from the ground or from other aircraft.

Another application in which a pilot will gladly relinquish control of aircraft to mechanisms, and in which the machine is superior to the man, is that of military target interception. In the future, a kamikaze will be outguessed by automatically controlled interceptors, which are far more accurate and deadly than any device relying alone on human perception and operation. A thermally or electrically sensitive seeker on the interceptor will sense the presence and position of the attacker; a computer will estimate the proper course for the pilotless aircraft, and servomechanisms will control the wing and tail surfaces of the interceptor in order that it may be able to intercept the attacker.

It becomes clear, then, that automatic control of aircraft is an important development in reducing fatigue and exhaustion of operating personnel, in increasing the reliability of flying in all kinds of weather, in opening up new uses for aircraft which would not otherwise be feasi-

ble because of danger to personnel, and in strengthening our national defenses. Each objective provides good reason for developing automatic controls for airplanes.

But it must not be surmised that automatic control of aircraft is the ultimate goal, or that all planes in the future will be operated by push buttons from the ground. Automatic control is no substitute for human intelligence, and not even the most refined controls will ever replace the commercial pilot. Moreover, depending upon how completely the aircraft is divorced from human domination, there are various degrees of automatic flight control. In all such automatic systems, however, it is important to remember that human intelligence must always initiate the control sequence, that it must be able to take into account factors for which the controls are not intended, and that it must make the decisions — sometimes vital — in the event of failure of automatic control equipment.

The Automatic Pilot

The design of an automatic pilot involves no witchcraft; rather it is merely one example (if an elaborate one) of principles which have long been known. The actions of the human pilot are critically analyzed to crystallize the functions to be demanded of the automatic equipment. The automatic pilot is then designed so that it may accomplish all essential operations in proper sequence.

By analogy with the human pilot, the automatic pilot must have directional sensitivity, somewhat akin to the pilot's vision; it must possess course discrimination corresponding to that which takes place in the pilot's brain; it must have a dispatching mechanism comparable to the pilot's nervous system; and it must initiate necessary action, much as the human pilot does with his muscles. In addition, the automatic pilot emulates his human counterpart by being able to store information temporarily and anticipate changes in physical conditions. The one attribute the automatic pilot cannot have is the human ability to learn. The automatic pilot is born full-grown and completely developed; the passage of time serves only to cause wear and tear and to invite senescence.

The unit providing directional sensitivity establishes a standard or reference direction which remains fixed with respect to the earth and is, of course, independent of the operation of the airplane. *(Continued on page 108)*

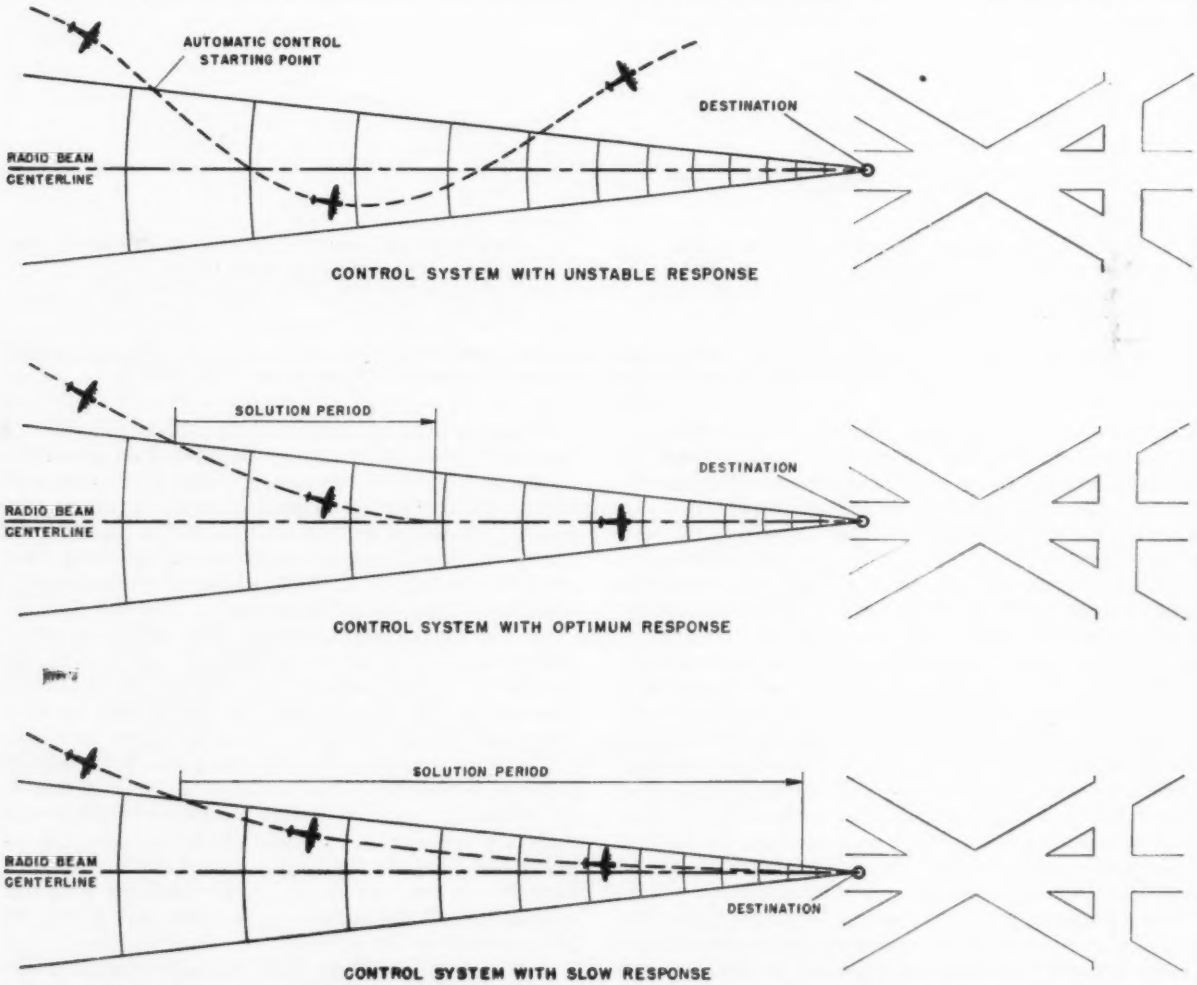


Fig. 3. Path of airplane in approaching landing field under automatic radio control for three different conditions of response. In the top diagram, automatic control is ineffective because response of the mechanism is unstable. In the center diagram is shown a system operating without overshoot and reaching the patch of the radio beam center line in the minimum solution time. In the lower diagram, applying to a control system with slow response, the plane takes unduly long to reach the center line to be guided to the plane's destination.

THE INSTITUTE GAZETTE

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Progress Report

OPENING the season's activities, when the 258th meeting of the Alumni Council of M.I.T. met in the Graduate House for its customary dinner and business meeting, were 139 members and guests. Raymond H. Blanchard, '17, newly elected President of the Alumni Association, presided and introduced other officers elected to serve for the coming year, as well as new Term Members of the Corporation and of the Faculty.

Charles E Locke, '96, Secretary, reported that earlier in the day the executive committee had approved 97 changes of class affiliations, mostly for veterans who after returning to the Institute preferred to be affiliated with classes with which they originally entered M.I.T., and that recognition had been given to the new M.I.T. Club of the Lehigh Valley. Since May, 37 visits to 19 M.I.T. clubs had been made by Faculty or staff members. In spite of increased costs, offset by increased advertising revenue, the year's operations for The Technology Review were in the black. New representatives of several local clubs were elected, as were also honorary secretaries. Henry B. Kane, '24, Alumni Fund Director, reported a 10 per cent increase in the total Fund, with average contributions of $18.30 as against $16.60 for a year ago. Resolutions for the late George W. Kittredge, '77, were presented by Andrew D. Fuller, '95, and these resolutions were accepted by standing in silence.

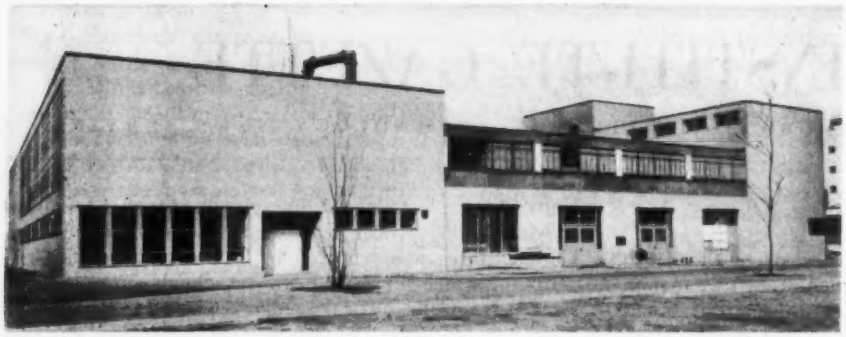
At the conclusion of the formal business of the meeting, President Blanchard called upon Wallace M. Ross, General Secretary of the Technology Christian Association, who spoke on developments at the Institute's Freshman Camp since it was organized in 1926, the fifth such camp to be inaugurated in the United States. For many years, the Freshman Camp activities were held at Lake Massapoag in Dunstable, Mass., and were highly successful in acquainting new students with the life they would lead at the Institute. During World War II it became necessary to give up outdoor camp activities but a suitable program of good fellowship, in which M.I.T. traditions were passed on to incoming freshmen, was held in Walker Memorial. This year, 524 freshmen, 26 counselors, and 15 Faculty members attended Freshman Camp at Camp Wonderland in Sharon, Mass. For the first time, women students participated in activities this year in an active week-end program which did much to start new students off properly in their new life at M.I.T.

Mr. Blanchard then called upon President Compton who had been scheduled to speak on latest developments at M.I.T. Dr. Compton announced that student registration had reached an all-time high of 5,630 and that it is estimated that the Institute's incoming class will reach its peak next year with 800 freshmen. At the same time, it is anticipated that total enrollment will drop to a figure between 4,600 and 5,000 students.

In summarizing the present status of higher education in this country, President Compton stated that the United States has about 1,700 schools of higher learning, of which 1,000 award degrees. Total enrollment in the United States was reported to be about 2,333,333 students, of which about half are in schools supported by state taxes. College enrollment is expected to increase to 3,000,000 by 1950. Because normal expansion was not possible during the war years, all schools and colleges are overcrowded at present. The large number of students who have entered college since the war place a burden on these educational institutions which has made it impossible for them to maintain the highest academic standards. In accordance with the thoughts expressed in his annual report to the Corporation, President Compton emphasized the need for the Institute, and other privately endowed institutions of higher learning, to provide outstanding training for superior students.

Also announced by President Compton was the progress which has been made in expanding educational facilities at the Institute. The projects include: (1) the new Senior House, ready in October, 1948, for which $500,000 has been contributed through the Alumni Fund; (2) the Army drill shed being transported to M.I.T.,

Donald F. Carpenter, '22, chairman of the Corporation Committee on Student Activity, Raymond H. Blanchard, '17, President of the Alumni Association, and George K. Parmelee, '48, President of the Institute Committee, watch President Compton break ground for the new Senior House now being built along Memorial Drive on Institute property west of Massachusetts Avenue.



The new Gas Turbine Laboratory of the Institute, equipped with the most advanced facilities for graduate instruction and fundamental research, was dedicated on October 7 at ceremonies attended by Army and Navy officers, members of the Corporation, and leaders in industry.

Speakers at the dedication ceremonies were Alfred P. Sloan, Jr., '95, chairman of the board of General Motors Corporation and a Life Member of the M.I.T. Corporation, and Gordon S. Rentschler, Life Member of the Institute's Corporation, head of its Visiting Committee on Aeronautical Engineering, and chairman of the National City Bank of New York. Guests were conducted on an inspection tour of the new laboratories illustrated here, as well as the adjoining Sloan Laboratories which were established several years ago. Following the inspection, President Compton entertained the guests at luncheon in the Graduate House, at which Marvin W. Smith, chairman of the Westinghouse Educational Foundation, and Rear Admiral Lawrence B. Richardson, '21, Vice-president of Curtis-Wright Corporation, spoke.

part of it to be used for an athletic cage, and the other part for air research in Bedford, to be ready March 1; (3) the full-time use of the Cambridge Armory for athletics and drill; (4) the new supersonic wind tunnel which is under construction; (5) the new Gas Turbine Laboratory dedicated in October; (6) the Charles Hayden Memorial Library, for which plans are being beneficially revised when it was found that the lowest of bids received was $1,000,000 above the funds available; (7) the new Hydrodynamics Laboratory and Towing Tank which is one of the must items of the future; (8) new Machine Tool Laboratory, for which a large amount of equipment is already on hand, which is another must item for the future.

Arthur G. Robbins: 1862–1947

ARTHUR GRAHAM ROBBINS, Professor Emeritus of Topographical Engineering, died at his home in Winchester, on October 26. Born in Carlisle, Mass., on July 11, 1862, he studied at M.I.T. from which he received his bachelor of science degree in 1886. The same year he joined the Institute staff as assistant in the Department of Civil Engineering. He became an instructor in civil engineering two years later, and an instructor in highway engineering in 1893. In 1896 he was made assistant professor of highway engineering and in 1906 became associate professor of topographical engineering. He was advanced to professor of topographical engineering in 1909, which post he held until his retirement in 1932.

William H. Jones: 1886–1947

WILLIAM HENRY JONES, Associate Professor of Heat Engineering, Emeritus, died on October 17 in Watertown. He was born in Cochituate, Mass., on June 27, 1886, and attended M.I.T. from which he received a bachelor of science degree in 1909. Two years later he joined the Institute staff as an assistant, and became an instructor in the Department of Mechanical Engineering the same year, 1911. He became assistant professor of experimental engineering in 1925, associate professor of experimental engineering in 1931, and associate professor of heat engineering in 1934. He became emeritus associate professor in June, 1947, and was active as a lecturer when he died.

Forthcoming Events

TIME, with its disquieting habit of progressing at a much faster pace than most of us acknowledge, will soon be beckoning us to attend the forthcoming gathering of Technology Alumni at the Midwinter Meeting to be held in Walker Memorial. This important event, for which Alumni in the metropolitan area of Boston gather annually for an evening of good fellowship, has been set for Saturday, February 7. Robert C. Casselman, '39, has been chosen chairman of the Boston Midwinter Meeting.

While on the subject of casting shadows of forthcoming events, it may be well to remind Review readers that Alumni Day, 1948, will be held on Saturday, June 12. William W. Garth, Jr., '36, chairman of the Alumni Day Committee, promises an outstanding symposium, along with the traditional class reunions and Stein-on-the-Table Banquet in the evening.

Albert A. Schaefer: 1884–1947

ALBERT ADAMS SCHAEFER, Professor of Law and Government and Director of the Puerto Rican Fellowship Program, died on October 23. Professor Schaefer was a native of Middletown, Conn., where he was born on February 25, 1884. He was educated at Phillips Exeter Academy and at Harvard College from which he received a bachelor of arts degree in 1906. Three years later he was graduated from the Harvard Law School.

Professor Schaefer's professional career in law began in Boston in the office of the District Attorney. In 1913 he began his association with the Boston firm of Ropes, Gray, Boyden, and Perkins, specializing in trial cases until his retirement from the firm in 1935.

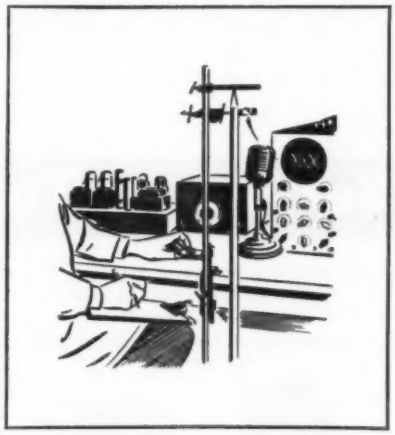
His association with the Institute began in 1930 when he was appointed special lecturer in law in the Department of Business and Engineering Administration. He was appointed assistant professor in 1931, associate professor in 1935, and was advanced to professor in 1940. In addition to his academic duties, he has been most active in the affairs of the Institute and was widely known among the student body with whom he was very popular. He has been a member of many committees and a past president of the Faculty Club.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

Most people think of brass tube as a mill product with a great many important industrial uses. It is regularly used to carry water and other liquids, to make parts of machines and appliances, railings, handles, and so on. Yet it also can be a musical item, in door chimes, and the story of its development for that purpose is an unusual one.

When electric door chimes appeared, it became evident that here was an entirely new requirement for brass tube—that it produce a pleasing tone when struck. The other factors that have made brass tube a staple, large-volume product for so many years, such as its rich color and corrosion resistance, dictated the choice of brass. Here, then, was the problem: what are the causes of pleasing tone in tube, and how can they be controlled in the mill in order to supply a reliably standard musical product?



The first step was purely experimental. Revere proceeded by ear. Over 100 samples of tubes in various alloys, tempers and gauges were hung up, struck, listened to, and preferences obtained from many people. These tests showed an outstanding preference for the tonal quality of one type of tube. But Revere did not stop there. It was desirable to know why that tone was preferred, what factors were responsible for it, and how they could be controlled.

The project then was turned over to a laboratory physicist who is also a talented musician. Now began the most ambitious and lengthy and scientific part of the work, employing the most modern electronic apparatus, including a beat-frequency oscillator and a cathode ray oscilloscope. These made it possible to dissect the tone produced, measuring the intensity and frequency of the fundamental note and its partials with an accuracy of one cycle per second. Much new information was developed concerning the source of the tone, the manner in which the tube vibrates, and the changes in the tone produced by changes in tube characteristics. The net result is that Revere really knows chime tube, scientifically, musically, physically, and, of course, how to produce it. We also know exactly how a chime tube should be plugged, and where struck, and why, which information is of value to door chime manufacturers.

As Revere contemplates the voluminous laboratory records of this work it realizes that interesting and important though it was, it is by no means a solitary example. Revere has repeatedly studied in the greatest detail both new and old applications of its mill products, and uncovered data of value in extending the life and usefulness of them. So, for that matter, has practically every other supplier of materials to industry. Hundreds of companies operate well-equipped, competently-staffed laboratories. Others employ college laboratories more or less steadily. The final results of these continuing studies are embodied in products and processes, and thus raise the standards of all American industry. In addition, in the majority of cases secrecy as to the information obtained is not imposed, and thus you can obtain not merely better products, but also much information of practical value in their use. It has been pointed out that those who pay for materials also pay for the brains required to develop them, and that therefore those brains should be used. Thus, Revere suggests that no matter what you buy, be it rubber or glass, chemicals or metals, cements or solvents, you would do well to draw upon the brains of your suppliers.

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AUTOMATIC CONTROL OF AIRCRAFT

(*Continued from page 104*)

A device called a comparator, or a course discriminator, compares this reference direction with the actual direction of travel of the airplane. It detects the discrepancy between the two directions and produces a signal or physical energy which is proportional to the divergence between the reference direction and the plane's course, that is, the output from the discriminator is proportional to the course error. The output signal from the comparator is distributed through the dispatching system in such a way that it initiates and actuates the required control mechanisms to bring the airplane back on its prescribed course. In the block diagram of Fig. 1 these functional elements are shown in a typical application for the control of pitch or elevation of a commercial aircraft.

To understand more fully the functioning of an automatic pilot it will be desirable to examine the several essential functional components, particularly as these may be used to control pitch or elevation in flight.

Course Indicator

On occasion, as for example on a clear day when he is coming down for a landing, the pilot receives information about his course by direct observation of the ground and he then requires no instrumental aids. On other occasions, he may determine his heading by scanning such instruments within the aircraft as the artificial horizon, the magnetic compass, and the radio compass. The network of radio beams, lacing the United States and tying together the important airports, offers a third method for course determination, for the pilot may "ride the beam" in flying from one airport to the next. The presence of the beam may be made evident to the pilot as a series of audible dots and dashes which he translates into the position of the plane with respect to the beam. The course indicator of an automatic pilot could be either the flight instruments within the aircraft or the detector of the radio beam.

Except for the periods just after take-off and just prior to landing, the flight plans usually require the airplane to fly at a constant altitude. The artificial horizon aids the pilot in meeting this requirement by indicating the pitch angle of the airplane with respect to horizontal. When the pitch angle is zero the airplane is in level flight and hence will maintain the desired altitude. As shown in the functional block diagram of Fig. 1 and the schematic operating diagram of Fig. 2, the sensitive element in the artificial horizon is the vertical gyroscope, commonly called a gyro, whose rotational axis is kept perpendicular to the surface of the earth by an erecting mechanism. The vertical gyro thus establishes, within the plane, a reference axis from which the pitch error of the plane may be determined and appropriate corrections made.

When engaging the automatic pilot an elevator trim adjustment is made manually until the airplane maintains the desired altitude. This adjustment is shown in the schematic diagram of Fig. 2 as a mechanical rack and

(*Continued on page 110*)

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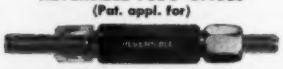

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THE RESPONSIBILITY OF MANAGEMENT IN THE BELL SYSTEM

IT USED TO BE that the owners of practically every business were themselves the managers of the business. Today, as far as large businesses are concerned, a profound change has taken place. In the Bell System, for instance, employee management, up from the ranks, and not owner management, is responsible for running the business.

This management has been trained for its job in the American ideal of respect for the individual and equal opportunity for each to develop his talents to the fullest. A little thought will bring out the important significance of these facts.

Management is, of course, vitally interested in the success of the enterprise it manages, for if it doesn't succeed, it will lose its job.

So far as the Bell System is concerned, the success of the enterprise depends upon the ability of management to carry on an essential nationwide telephone service in the public interest.

This responsibility requires that management act as a trustee for the interest of all concerned: the millions of telephone users, the hundreds of thousands of employees, and the hundreds of thousands of stockholders. Management necessarily must do the best it can to reconcile the interests of these groups.

Of course, management is not infallible; but with its intimate knowledge of all the factors, management is in a better position than anybody else to consider intelligently and act equitably for each of these groups—and in the Bell System there is every incentive for it to wish to do so.

Certainly in the Bell System there is no reason either to underpay labor or overcharge customers in order to increase the "private profits of private employers," for its profits are limited by regulation. In fact, there is no reason whatever for management to exploit or to favor any one of the three great groups as against the others and to do so would be plain stupid on the part of management.

THE BUSINESS cannot succeed in the long run without well-paid employees with good working conditions, without adequate returns to investors who have put their savings in the enterprise, and without reasonable prices to the customers who buy its services. On the whole, these conditions have been well-met over the years in the Bell System.

Admittedly, this has not been and is not an easy problem to solve fairly for all concerned. However, collective bargaining with labor means that labor's point of view is forcibly presented. What the investor must have is determined quite definitely by what is required to attract the needed additional capital, which can only be obtained in competition with other industries.

AND in our regulated business, management has the responsibility, together with regulatory authorities, to see to it that the rates to the public are such as to assure the money, credit and plant that will give the best possible telephone service at all times.

More and better telephone service at a cost as low as fair treatment of employees and a reasonable return to stockholders will permit is the aim and responsibility of management in the Bell System.

Walter S. Gifford

WALTER S. GIFFORD, *President*
AMERICAN TELEPHONE AND TELEGRAPH COMPANY

AUTOMATIC CONTROL OF AIRCRAFT

(*Continued from page 108*)

pinion. The displacement of the reference marker on the rack, with respect to the axis of rotation of the vertical gyro, is the indicated pitch error which the automatic pilot continuously minimizes. Before the corrective control can be effected, the indicated pitch error must be translated into a signal that can be so transmitted to the controls by the dispatcher. Usually, this signal is in the form of electrical energy but mechanical and pneumatic signals also have been found satisfactory.

Dispatcher

The airplane has an unsymmetrical control system. Changes in vertical direction result simply from the use of the elevator as shown in the schematic diagram, but right and left changes in direction are complicated by the necessity for banking. Unless the rudder is properly co-ordinated with the ailerons, slipping and skidding may result. Imperfect turns of an airplane have their counterparts in automobiles whose drivers take corners too sharply and too fast. An electrical unit within the aircraft sorts the error signals, measured about vertical and horizontal axes; takes cognizance of co-ordination signals from flight instruments; and dispatches signals to the servo units that position the elevator, ailerons, and rudder.

In the simplified diagrams of Figures 1 and 2 attention has been directed solely to travel in a vertical plane. In this elementary case the dispatcher is shown as actuating only the elevator.

A servo unit is installed in the airplane for each control surface to convert the signal from the dispatcher into the required corrective action. The servo units are normally powered by electric motors, although hydraulic actuators have been used in the past and still have certain advantages. The high-speed servo motors are geared to slow-turning drums, around which are wrapped cables connected to horns on the control surfaces. The rigging of an airplane can be compared with that of a sailing vessel, except that the blocks and pulleys are inside the ship rather than "out in the breeze." A signal from the dispatcher calling for action of the control system is answered by the servo motor which rotates the cable drum similarly to the capstan of a power windlass. The cable drum, through the cable, pulls on one of the dual horns of the control surface, and forces the surface into a new and presumably correct postion.

Static Performance Factors

The course indicators, control dispatcher, servos, rigging, and control surfaces are items which have special characteristics. These devices, in combination with the airframe, form a complex but co-ordinated system for providing the desired automatic flight control. Today's aircraft are designed with their maximum control-surface loads sufficiently balanced for pilot-stick forces of 75 to 100 pounds to produce desired deflection of all control surfaces. In the event of a mechanism failure, the automatic pilot can be de-energized by the use of a disengaging lever, and the human pilot permitted to regain direct

(*Continued on page 112*)

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AUTOMATIC CONTROL OF AIRCRAFT

(*Continued from page 110*)

control of the airplane. So long as the automatic control merely relieves the pilot, the premium on dependability is not as high as will be required with future aircraft, which may be so large that completely reliable automatic control will be necessary for all flight.

Designers of future equipment will be increasingly challenged with the economic factors of weight and size, in addition to reliability. A single unessential pound of metal in a casting installed in an airplane costs an air line approximately $75 a year. Equipment must be small and compact, or it will never fit into the contours of the wing and fuselage.

Consideration of power is the final static design criterion. While providing increased reliability and power, designers must also watch the weight and size of aircraft equipment with the avidity of a dieting matron.

Dynamic Performance Factors

In any automatic control system, component errors can accumulate with surprising results. As shown in Fig. 1, a part of the output energy is compared to that at the input of a closed loop. Such a closed loop constitutes a regenerative system in which small fluctuations in the input can build up to violent proportions if the magnitude and direction of the energy fed back to the system is not properly controlled. The speed of response of the component elements, as well as of the system as a whole, must also be suitably designed, for the system loses stability if the response is too rapid. Stabilization may be achieved, therefore, by slowing reaction time.

When an airplane is flying at high altitude toward a distant airport, the time necessary to correct an error in the course resulting from a random gust may not be critical. However, when the airport is approached and permission for landing is granted, it is important to get onto the landing beam as quickly as possible. A beacon properly aligned with the runway transmits a conical radio beam which is received by the incoming aircraft. A departure of the incoming aircraft from the center line of the beam can be recognized by noting the resulting increase in signal detected by a radio receiver in the aircraft. These signals can be indicated by a special flight instrument that informs the pilot whether his aircraft is over or under, or to the left or right of the landing path. This equipment permits the pilot to make a blind landing, and its use is called the instrument landing system.

Equipment for securing automatic landing is now undergoing development and test. For this equipment to function properly, the signal detected by the radio receiver must be transmitted continuously to the control servos via the dispatcher. The performances of three possible automatic systems in producing controlled landings are illustrated in Fig. 3. As shown, one automatic system reacts so rapidly that it bounces the airplane out of the radio beam, and hence is unstable and unsatisfactory. At the other extreme is an automatic system so sluggish

(*Concluded on page 114*)

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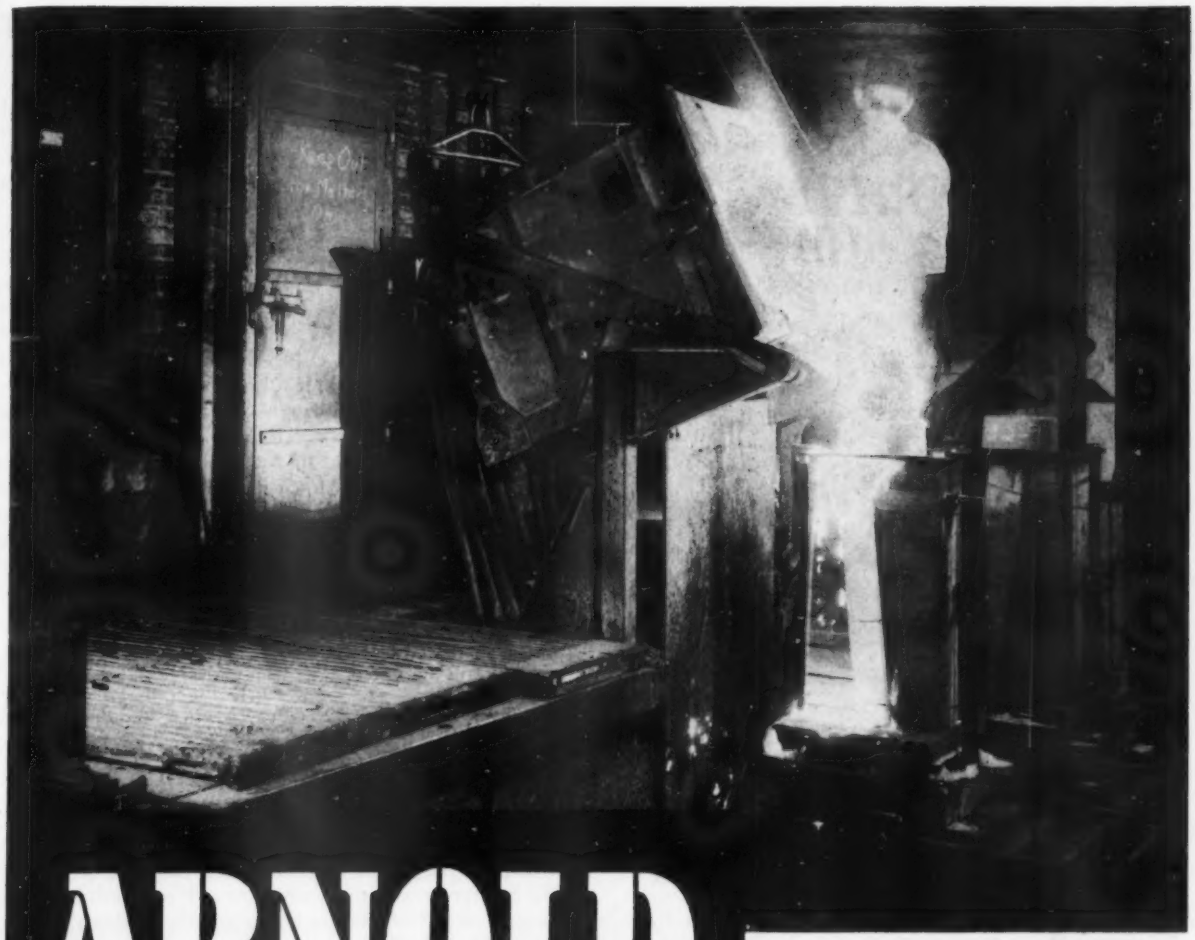

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C-646	Std.	1″	3-3/16″	2500	5150
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AUTOMATIC CONTROL OF AIRCRAFT

(*Concluded from page 112*)

that the airplane almost reaches the touchdown point before the solution period is completed. The automatic control with optimum dynamic characteristics is stable, and has a solution period which is relatively short compared with the total landing period.

In order to obtain optimum performance, the automatic control must be tailored for a given type of aircraft. It is essential that the stabilizing constants of the automatic control match the dynamic characteristics of the particular airframe. Most present-day automatic control contains provision for screw-driver adjustments of the stabilizing constants. These adjustments must be set by a cut-and-try process, and frequently the available range of adjustment is insufficient. Techniques that will permit a more accurate appraisal of the desired adjustments are currently being explored. However, a tremendous number of test flights must be analyzed before dynamic designs can be imbued with accuracy sufficient to eliminate completely the necessity for flight adjustments in newly designed aircraft.

The Guided Missile Problem

A most intricate automatic control system is needed in a guided missile used to intercept a high-speed target. The technique is similar in principle to the automatic landing procedure, but the rates of closure between missile and target are so rapid that the solution period is considerably shorter.

If the guided missile is to intercept the target as quickly as possible, it must carry a course computer to anticipate the target motion during the time of closure. The hunter never fires directly at a flying bird, but aims his gun ahead of his quarry; similarly, a dog does not chase the tail of a rabbit, but tries to anticipate the rabbit's motion by heading him off. A determination of the expected target motion permits a similar aiming of the guided missile at a point in advance of its victim.

The Instrumentation Laboratory at M.I.T., under the direction of Dr. Charles S. Draper, '26, has been designing computers of target lead for nearly a decade. The operation of the computer is based upon the principle that, when a pursuing airplane is continuously pointed at a moving target, the rate of turn of the airplane is directly associated with the lead necessary to anticipate a future collision with the target. When the desired lead, as indicated by the course computer, is equal to the actual lead, as measured by the course indicator (the seeker), the missile is assumed to be on course and no corrective action is required. When computed lead is not equal to actual lead, a correction must be applied to the controls.

In conclusion, the field of aircraft automatic control offers an intellectual challenge to the engineer. In order to comprehend a given system, the engineer must have a reasonable command of mathematics, aeronautics, electronics, mechanics, and instrumentation. He must have the imagination to use the best combination of the equipment developed by each of these fields in order to design a given system. His goals must be improvement in the safety of present-day travel and a broadening of the scope of future travel to include all-weather flying. Inevitably, he must not overlook the applications of his craft to weapons which will ensure the military security of his country.

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HOW LONG WILL OUR METALS LAST?

(*Continued from page 101*)

certain purposes. It is an important constituent of stainless steel and increasing amounts are being used.

New discoveries of nickel ore deposits are being made from time to time in Canada and other parts of the world and there seems to be no great alarm regarding depletion of world supplies.

Several other metals are of interest principally because of their use as constituents of important alloy steels. These are manganese, chromium, tungsten, vanadium, and molybdenum. The United States has ore deposits of all of these but is self-sustaining only in molybdenum.

The United States Bureau of Mines has developed a process for producing pure metallic manganese by depositing it electrolytically from acid aqueous solutions. No important uses have yet been developed for metallic manganese as such but the electrolytic material is being used to alloy with other metals and is particularly of value when an iron-free manganese alloy is desired. Our domestic manganese ores are low grade, difficult to use, and, on the whole, less satisfactory than high-grade imported ores. Our principal imports are from Russia, India, Brazil, Cuba, and Africa.

Chromium is used as a minor constituent in several alloy steels and in larger amounts in stainless steel. It is also used extensively for chromium plating. In addition to this, chrome ores are used for making refractory brick used in some smelting furnaces. Chrome ores are imported from New Caledonia, Rhodesia, South Africa, Turkey, and other countries.

Tungsten is essential for high-speed, tool steel and is used in smaller amounts for incandescent lamp filaments. The deposits in our northwestern states do not supply our needs. China makes up the deficiency.

The principal use for vanadium is in tool steel where small percentages are beneficial. The United States has several mines but they do not supply all our needs. The deficiency is made up by importations from Peru.

Molybdenum is a relatively newcomer in the alloy steel field but it has made an important place for itself in various types of structural and tool steels frequently associated with chromium as an alloying agent and often in small amounts. The world's largest known deposit is the Climax mine in Colorado and for a time this supplied practically all the world's needs. Deposits have now been developed at several points in this country and in other countries. A substantial tonnage of concentrates is being produced in this country as a by-product of copper concentration. It is present in such small amounts in some copper mines that until recently it was neglected but in the perfecting of concentration methods it was found that the molybdenite mineral could be profitably segregated and marketed. Pure metallic molybdenum has been produced and at present finds a minor use as wire and sheet but it is possible that these uses may be expanded. Resources in molybdenum seem to be adequate for an indefinite period.

Cobalt is a metal which has been used to a limited extent in alloy steels and more recently in conjunction with tungsten carbide for high-speed cutting steel tools. It is attracting increasing attention and research is developing important uses for it.

(*Continued on page 118*)

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HOW LONG WILL OUR METALS LAST?

(*Continued from page 116*)

Zirconium is a metal which is little used at present but may have some interesting uses. Research laboratories are studying its alloys with copper and other metals and some valuable properties are already indicated.

Titanium is a widely distributed element and many large deposits are known in this and other countries. If it comes into general use, however, it is doubtful if this country would be self-sustaining. At present titanium oxide is being increasingly used in paint manufacture. Titanium alloys with copper have properties resembling tin bronze. Ductile titanium has been produced and we shall doubtless be hearing more of the metal and its alloys. Since titanium is so abundant in the earth's crust we should use it to supplement our nonferrous metal supply.

Beryllium is one of our lightest metals but it can never compete in quantity production with such light metals as aluminum and magnesium. The only mineral of beryllium which has been found in sufficient quantity to serve as an ore is beryl and here the beryllium oxide is chemically combined with silica and alumina making a low-grade mineral which must be broken up by expensive chemical methods followed by other expensive treatment for recovery of the metal. Also beryl is by no means abundant and is expensive to mine. It seems doubtful if beryllium can ever be produced for less than $2.00 per pound which definitely limits its use in the pure state to special purposes or as an alloying constituent where it forms a very minor part of the alloy.

The United States produces considerable antimony as a by-product in lead refining but this country is far from self-sustaining. The world's largest producer is China.

Cadmium is frequently associated with zinc and most of the world production comes as a by-product from smelting or leaching zinc concentrates. A minor amount is produced as a by-product of lead smelting. Cadmium is frequently a constituent of alloys having low fusibility. It is also used for coating steel which may be subjected to salt water corrosion. Some cadmium compounds are used for pigments. It is not available in large quantities and expansion of uses is limited for this reason.

Mercury, sometimes called quicksilver, is the only metal which remains liquid at ordinary temperatures. Most of the world's supply is produced in Italy, Spain, and the United States. It is used for making amalgams, as a detonator for explosives, and for making such instruments as thermometers and barometers. Some interesting experiments have been carried out which show that mercury is more efficient than water when used in boilers. This is only of academic interest however for the world's known deposits would supply only a relatively few plants. Small amounts of mercury compounds are used in the drug industry. The known supplies of mercury are not large but the uses are not expanding.

Thorium and uranium are now attracting world attention. The possible use of the former is intriguing but the latter is definitely of extreme importance.

It can hardly be said that uranium is a new metal. As long ago as 1922 a student in the M.I.T. Metallurgy Department studied the effect of uranium additions to steel. The present interest in uranium, however, is due to a property unthought of at that time.

(*Continued on page 120*)

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HOW LONG WILL OUR METALS LAST?

(*Continued from page 118*)

Extravagant prophecies have been made regarding the use of fission products from uranium for power purposes and in the light of our present knowledge it would be presumptuous to say they are not possibilities. It is fair to point out, however, that publicly known deposits of uranium ore are not extensive and the uranium content is not high. The making of a suitable concentrate and its reduction to metal is costly and the treatment of this metal to separate the relatively small amounts of desirable isotopes is still more costly. Discovery of considerable additional ore and substantial reduction in extraction costs would seem to be necessary if atomic power is to compete with other sources of power on a world-wide basis. Of course if thorium or other elements become equally satisfactory as uranium the picture may change.

Regardless of the future use of atomic power, we have with us at the moment two uses of fission products which are not dependent on large production or low cost. The first is beneficial and is being eagerly experimented with by the medical profession. The world welcomes the use of these radioactive materials which may cure many human ills. The other use is diabolical and has possibilities of unbelievable destruction.

A material which is known to have such stupendous possibilities for good or ill should not be in the control of any individuals or separate nations but should be held in trusteeship for all of humanity.

Trusteeship of fissionable materials must be exercised at the source if it is to be effective. No formula for bringing this about is proposed but it is imperative that these materials be made universally available for human advancement and kept out of the hands of those who would destroy. Any method which does not start with control of the initial output seems doomed to failure.

General Conclusions

It is obvious that general economic laws will have a marked effect on the depletion of our metallic resources. It is inevitable that, as prices for any one metal rise, nonessential uses will decline and substitution of other metals and nonmetals will take place. Also, countries which have a shortage will import from countries having abundance.

As long as fear of war prevails, each country will try to become self-sustaining as far as possible, but unfortunately this goal is impossible of complete attainment.

The United States is far better provided with metallic resources than any other nation but its consumption is large and the country is deficient in several elements. Ever since World War I a few far-sighted men have urged the stock-piling of several years' supply of vital ores. The number of such men is increasing but they meet opposition from others who are interested in developing such resources as we have.

The writer is in complete sympathy with the first group and makes a few suggestions from that point of view:

(1) Even in cases where we are self-sustaining, if a deficiency is not far away we should encourage moderate importation of ores and concentrates and possibly metal. In such a class would fall iron, copper, lead, and zinc.

(2) We should import and stock-pile manganese ores, chrome ores, tin ores, and tungsten ores. Our manganese

(*Concluded on page 122*)

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HOW LONG WILL OUR METALS LAST?

(*Concluded from page 120*)

ores are, in general, low grade and require expensive beneficiation. With an abundance of foreign ore available our own supplies should remain in the ground for future generations. Chrome and tungsten mining should proceed at a moderate rate and be frankly supplemented by foreign importations.

(3) We are completely deficient in tin ore deposits and yet are the world's largest consumer of tin. We should stock-pile both metal and concentrates and encourage research for finding suitable substitutes for tin in various fields of use.

(4) The United States has no nickel deposits. Canada has the world's largest and also has substantial deposits of copper, lead, zinc, and platinum. Suitable reciprocal relations with Canada would solve our problems in these metals.

(5) We should promote research which tends to bring about conservation of all metals which are scarce on a world basis.

(6) War is our greatest waster of metals and fear of war hampers free exchange of ores and metals in world trade. We should therefore be unremitting in our efforts to promote peace and then approach the subject of metal resources as an international problem. By taking a long-range view it is obvious that the world supply is definitely not inexhaustible.

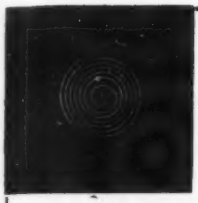
X-RAYS AGAINST CANCER

(*Continued from page 95*)

designed since the war in Dr. Van de Graaff's laboratory is being reproduced in several of the world's principal nuclear research laboratories, among them Cockcroft's National Nuclear Laboratory at Harwell, England, Joliot's laboratory in the College de France in Paris, and the National Research Council's Chalk River Laboratory in Canada. Several dozen electrostatic accelerators scattered about the world, notably including those designed by Professor R. G. Herb at the University of Wisconsin, have been used in research which has made important contributions to the knowledge of nuclear processes.

Back in 1934 the realization that electrostatically generated voltages could also be used in the production of unusually penetrating x-rays for deep therapy led to the opportunity to build the one-million-volt air-insulated generator for the Huntington Memorial Hospital. This machine and its building were financed by the Godfrey M. Hyams Trust, a Boston philanthropy which has continued loyally to support the high-voltage medical work at M.I.T. On March 1, 1937, the first patient was treated at the Huntington, and during the subsequent four and a half years well over 1,000 patients were given complete treatment series. This pioneering effort in radiology disclosed at an early date the great benefits that could be derived in avoiding skin damage and increasing the depth dose by use of roentgen rays produced by several times the standard voltage. In 1939 development of a compact one-and-a-quarter-million volt gas-insulated x-ray source was undertaken for the Massachusetts General Hospital. This generator was

(*Continued on page 124*)



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X-RAYS AGAINST CANCER

(*Continued from page 122*)

placed in use in April, 1940, and has since been in continuous clinical use. Between 15 and 25 patients are treated daily with the equipment developed and built at M.I.T., and the voltages now generally used with this apparatus lie in the range between one and a quarter and one and a half million volts. This work has further confirmed the desirability of supervoltages in the treatment of certain types of malignancies and has emphasized the need to investigate the efficacy of roentgen rays produced at still higher energy levels. The electrical engineering group at M.I.T. extended its efforts to the development of a higher-voltage x-ray source for Philadelphia's American Oncologic Hospital. The first generator for Oncologic, completed during the war, was requisitioned by the U. S. Army for nuclear research at Chicago. Its successor, a tiltable two-million-volt unit now nearly ready for delivery, is the most compact supervoltage x-ray source yet seen. Meanwhile, the supervoltage x-ray generator at Technology has made possible the extension of pioneering clinical researches to three million volts and is now being modified to bring the voltage to five million volts.

Present Therapy Spectrum

At no time in medical history have so many types of ionizing radiation been available for therapy and research. Artificially radioactive substances produced within the nuclear pile or by the cyclotron, roentgen rays produced by betatrons with energies up to 100 million volts, high-energy cathode rays, and well-collimated beams of neutrons and protons are all under investigation or proposed for use on the deep-tumor problem. Artificially radioactive substances are of unique and fundamental importance as tracers in biological and clinical research, but only a few materials such as radioiodine and radio-phosphorus have thus far found limited therapeutic use. Roentgen rays with energies much higher than a few million volts may actually become less desirable for therapy because of the increasing narrowness of the radiation beam at the very high energies and the seriously high exit dose which once again produces skin damage. High-energy cathode rays, which behave like bullets in the sense that they produce no damage in the body beyond their maximum range, are still too new to be fully evaluated, but may find an important place in the future. Cyclotron-produced neutron beams have been investigated for about 10 years at the University of California, with interesting but inconclusive results to date. While all of this spectrum of ionizing radiations will need to be thoroughly studied, it is already clear that roentgen rays produced by a few million volts have the most direct connection with the extensive roentgen therapy experience of the past and offer very significantly improved properties for the treatment of deep malignant tumors.

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(*Concluded on page 126*)

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X-RAYS AGAINST CANCER

(Concluded from page 124)

developed a corresponding need for a reliable commercial source of such devices. Toward the end of 1946, after efforts to utilize existing companies, the High Voltage Engineering Corporation was organized in response to this urgent requirement. Located in a plant near Harvard University, staffed in part by men who participated in the wartime electrostatic program of the Institute and with consultants from M.I.T., the University of Wisconsin, and Rice Institute, this company has gathered the best scientific experience in this important and difficult technique for the benefit of science and medicine. The new enterprise was financed by the American Research and Development Corporation, recently organized by leading New England citizens, including Senator Ralph E. Flanders of Vermont and Harvard's General Georges F. Doriot, who is its president. Advised by Technology's President, Karl T. Compton, Professor Edwin R. Gilliland, '33, of the Department of Chemical Engineering, Jerome C. Hunsaker, '12, Head of the Departments of Aeronautical and Mechanical Engineering, and others, the American Research and Development Corporation has the purpose of encouraging the development of new industries with strong roots in science. No organizational or financial connection exists between Technology and the High Voltage Engineering Corporation, but a mutual appreciation of the need for adequate commercial development of the products of scientific research has created an atmosphere of common endeavor. The High Voltage Engineering Corporation is headed by Dr. Denis M. Robinson, who was Commonwealth fellow at M.I.T. in 1929, scientific representative of the Telecommunications Research Establishment (Britain's radar development laboratory) assigned to the Radiation Laboratory at M.I.T. during the war, and in the first postwar year chairman of the Department of Electrical Engineering at the University of Birmingham in England.

Typically a product of modern times, the High Voltage Engineering Corporation is building the latest tool for medical science against cancer — a compact two-million-volt x-ray source fully as flexible as conventional lower-voltage equipments. Such two-million-volt generators, engineered for therapy and science, are already scheduled for shipment to leading medical and research institutions in England, France, and the United States. At the same time, recognizing that it possesses the knowledge and ability for creating one of the most powerful tools for nuclear research, this company is undertaking the production of electrostatic positive-ion accelerators of still higher energy rating. It is hoped that by this means not a few of the products of fundamental science and engineering may become available for the full use and benefit of all mankind.

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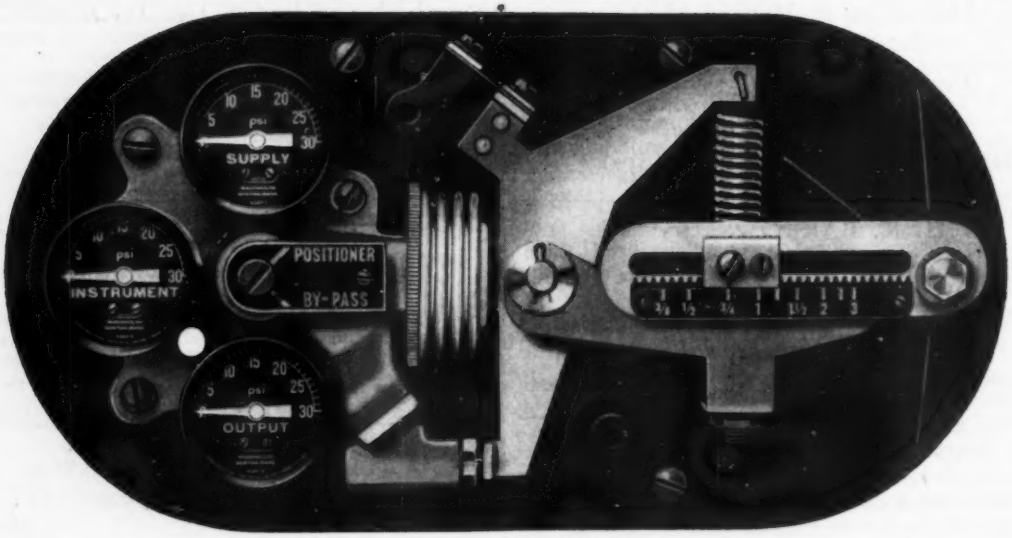
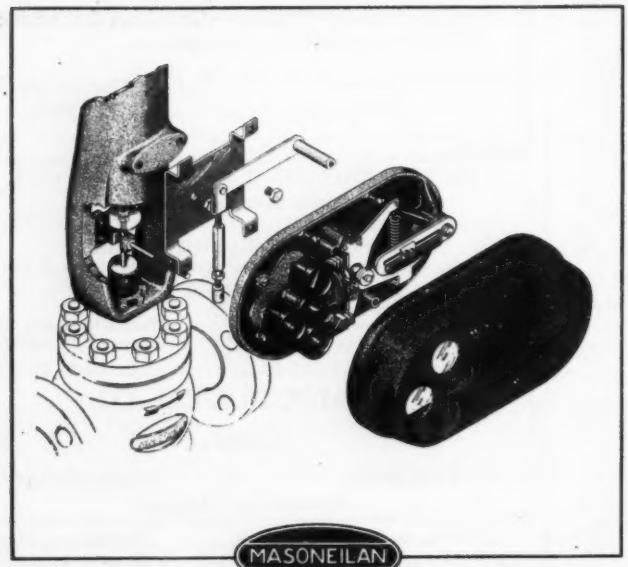


Interior View

CONTROL VALVE POSITIONERS



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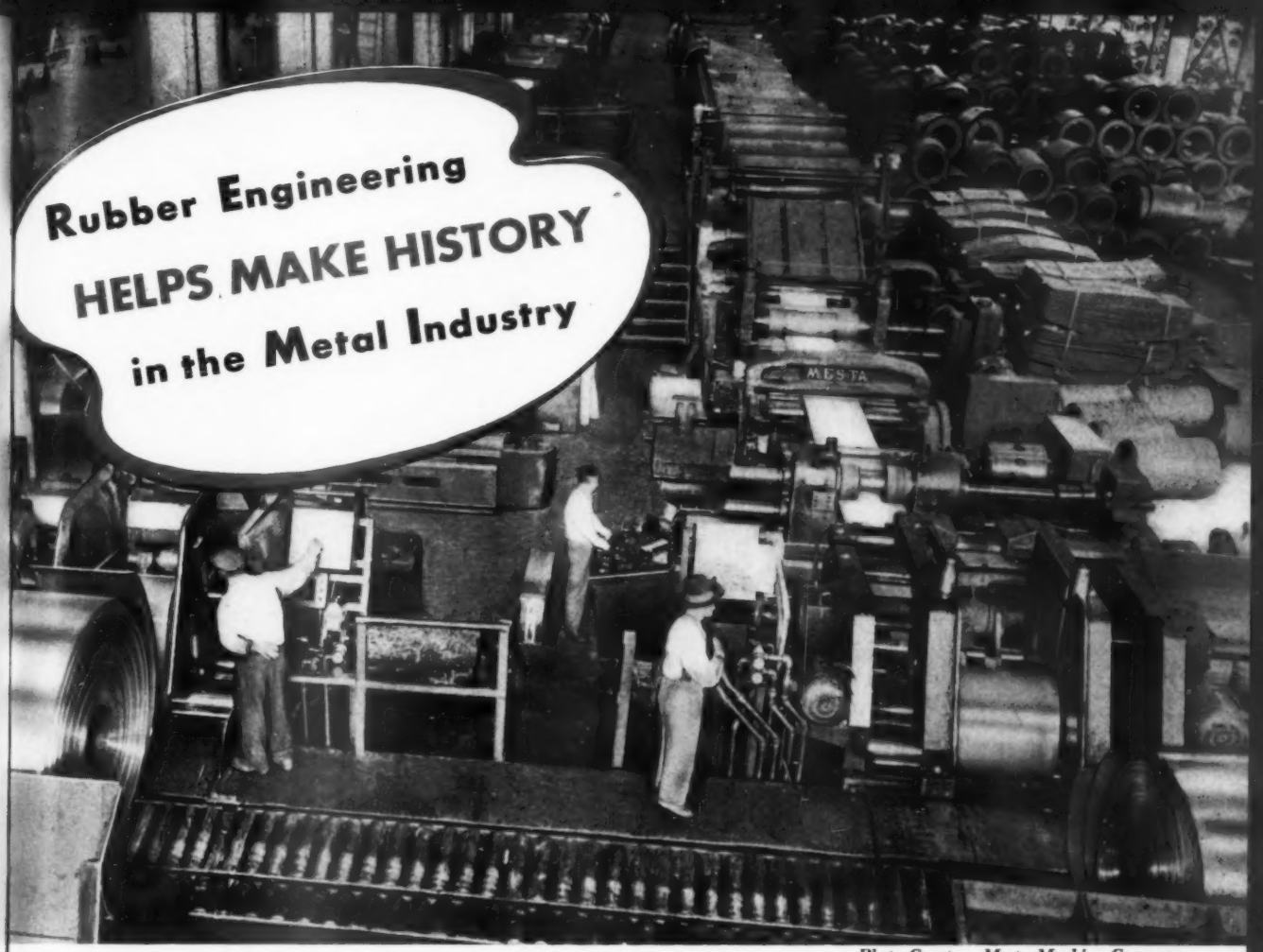

Photo Courtesy Mesta Machine Company

When a large steel plant demanded a faster method of pickling sheet steel, engineers literally made history in the steel industry with specifications for the huge continuous strip pickling lines pictured above.

Playing a major collaborating role—with one of the most vital materials required in the specifications—were the Manhattan engineers and their knowledge of rubber. Applying their technical skill and background of 40-years' rubber lining experience, they helped solve every problem of rubber lining and rubber covering this giant job presented.

The line featured above is rubber-protected 100% by Manhattan including rubber-lined drip-troughs, rubber-lined piping, rubber-covered rolls, and other rubber products.

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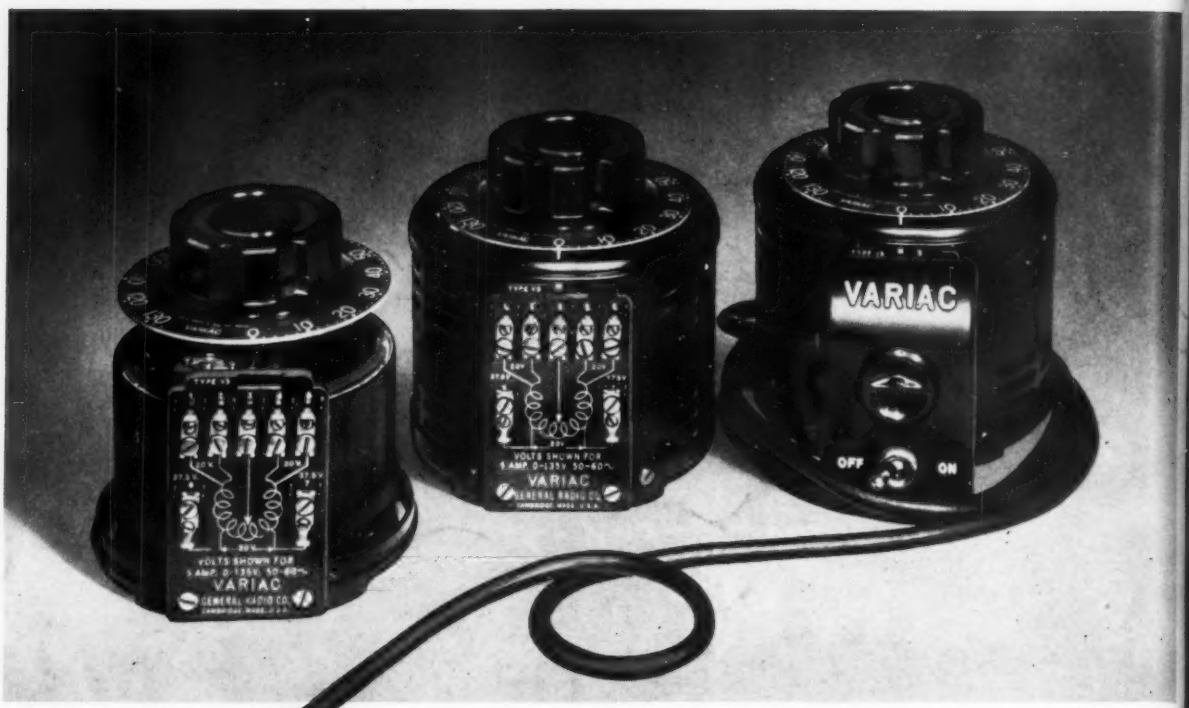

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We have been concentrating our VARIAC production facilities on this model and are gradually getting out of the woods.

The Type V-5, like others in the new "V" series, is a decided improvement over its predecessors. Lighter in weight by 25%, with new unit brush construction which cannot cause damage to the winding if the brush wears down, having a heavy-duty line switch, equipped with a polarity indicator in the convenience "load" outlet, provided with a new molded terminal plate for either screw or solder connections, and furnished with a newly designed knob and dial with big calibration figures for reading at a distance, these new VARIACS are more convenient to use . . . more efficient in operation . . . last longer.

The VARIAC is the *ideal* a-c voltage control. It has the convenience of the rheostat with the efficiency of the transformer; unlike a rheostat it provides control voltages 17 per cent *higher* than the line voltage . . . and these voltages are continuously adjustable from ZERO.

SPECIFICATIONS†	115-Volt TYPE V-5	230-Volt TYPE V-5H
LOAD RATING (KVA)	.862	.575
Input Voltage	115	230 or 115
Output Voltage, ZERO to	135 or 115	270 or 230
Rated Current (Amps.)	5	2 or 1
Max. Current (Amps.)	7.5	2.5
PRICE—Unmounted (1)	**TYPE V-5 $18.50**	**TYPE V-5H $21.00**
" —Cased (2)	**TYPE V-5M 20.50**	**TYPE V-5HM 23.00**
" —Mounted (3)	**TYPE V-5MT 25.00**	**TYPE V-5HMT 27.50**

(1) At left in illustration
(2) Center of illustration
(3) At right of illustration
† All performance data for 60-cycle operation

The 230-volt models (V-5H) are similar in external appearance and size to the corresponding 115-volt (V-5) units shown in the illustration

** Reg. U. S. Pat. Off. VARIACS are patented under U. S. Pat. No. 2,009,013 and British Pat. No. 439,567. The VARIAC — and original continuously-adjustable transformer — is manufactured and sold exclusively by General Radio Company or its authorized agents.*

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